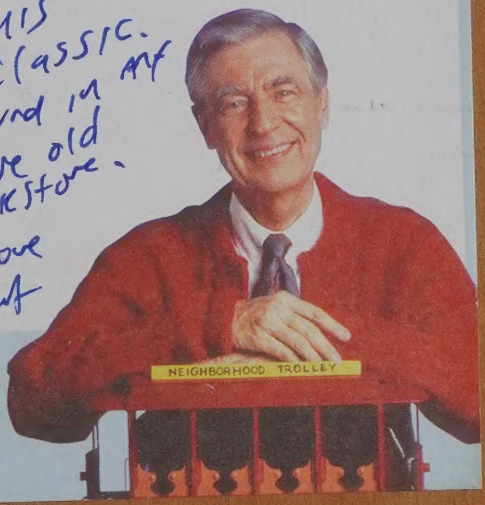
☑ YOU'RE SPECIAL ☑ I LIKE YOU JUST THE WAY YOU ARE
☐ WOULD YOU BE MINE? ☐ COULD YOU BE MINE?

Mom:
Thought you would enjoy this classic. Found in fave old Bookstore.
Love
Robert



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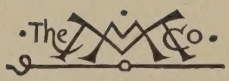
1909

A TEXT-BOOK OF PSYCHOLOGY



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A TEXT-BOOK OF PSYCHOLOGY

BY

EDWARD BRADFORD TITCHENER

PART I

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TO THE MEMORY OF

JOHN SCOTT BURDON SANDERSON

PREFACE

The present work has been written to take the place of my *Outline of Psychology*. The *Outline*, which was stereotyped in 1896, had long passed beyond the possibility of revision, and the continued demand for it showed that there was still room in the science for a text-book which set experimental methods and experimental results in the forefront of discussion. I should have preferred, however ungratefully, to let the book die its natural death; for I feared that it would be impossible to recover the freshness and vigour of the first writing, and I knew that another issue would lay an oppressive tax upon future time and energy. But colleagues and pupils and publisher were insistent, and I finally decided to rewrite. This Part I. contains, approximately, half of the new work; Part II. will appear, I hope, in 1910. In the meantime, the last edition of the *Outline* will be kept upon the market: as soon as the *Text-book* is complete, it will be withdrawn.

It is, I think, unnecessary to apologise for the increase in size. If psychology is to be taken seriously, its problems must nowadays be treated in some detail. Besides, the *Text-book* aims, within its limits and upon the elementary level, at systematic completeness; it is not a digest or redaction of a larger work, to which the student may be referred for further information. I could wish, remembering some of the criticisms called forth by the *Outline*, that I had a fully elaborated Systematic Psychology to fall back upon; but I am inclined to believe that, from the

student's point of view, a text written expressly for the class-room is more satisfactory than the simplified version of a book written primarily for psychologists.

The *Text-book* follows, in general, the lines laid down in the *Outline*. The only point that calls for special mention here is, perhaps, the scant space accorded to nervous physiology. Readers of the Introduction, and especially of § 9, will acquit me of any desire to minimise the importance of this subject. But I have always held that the student should get his elementary knowledge of the nervous system, not from the psychologist, but from the physiologist; the teacher of psychology needs all the time at his disposal for his own science. It is true that psychology, if it is to be explanatory, must supplement the description of mental processes by a statement of their physiological conditions. But then it is also true, unfortunately, that any such statement, in the present condition of our knowledge, must be largely hypothetical. In a comprehensive work, discussion of the various physiological theories, for instance, of feeling and attention would be altogether in place; to discuss them with beginners strikes me, I confess, as a sheer waste of time. My own plan is to show, by reference to the theory that appeals to me at the moment as the most plausible, how in principle an explanation is to be worked out. But I am careful to say that the theory itself is simply guess-work, that many other guesses have been made, and that there is a great gulf fixed between established physiological fact and the secondary constructions of physiological psychology.

My thanks are due to my wife, and to my colleague, Professor I. M. Bentley, for constant advice and assist-

ance during the preparation of this part of the *Text-book*. I dedicated the third edition of the *Outline* to the Regius Professor of Medicine in my old university; it was he who, in 1890, suggested the writing of the book. Sir John Burdon Sanderson has now laid down a life full of years and honours. I owe him — as who of his pupils does not? — a heavy debt of gratitude; and I dedicate the *Text-book* to his memory.

CORNELL HEIGHTS, ITHACA, N.Y.
May 1, 1909.

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A TEXT-BOOK OF PSYCHOLOGY

A TEXT-BOOK OF PSYCHOLOGY

SUBJECT-MATTER, METHOD AND PROBLEM OF PSYCHOLOGY

§ 1. **Science and Experience.** — A science consists of a large body of observed facts, which are related to one another, and are arranged under general laws. If, for instance, you open a text-book of physics, you find that it gives the results of numerous observations, or prescribes experiments in which you are to observe for yourself; and you find that these results or experiments are grouped under certain main headings (mechanics, heat, electricity) and are made to illustrate certain comprehensive laws (Newton's laws of motion, Kirchhoff's law of radiation, Ohm's law of the strength of the electric current). All scientific text-books, whether the science is physics or chemistry, biology or psychology, philology or economics, are of the same pattern.

It is worth while, before we begin our special study of psychology, briefly to consider some of the questions which this definition of science suggests. How, we may ask, do the various sciences come into being? How are they differentiated, their several fields laid out and marked off? What do we mean when we say that the facts of any given science are related to one another? What is the nature of the relation? What precisely is a scientific

law? Why is it important for the progress of science that laws should be established? An answer, even a rough answer, to these questions will help us to understand the scope and aim of psychology.

First of all, then, it is plain that all the sciences have the same sort of subject-matter; they all deal with some phase or aspect of the world of human experience. If we take a mere fragment of this world, — say, our own experience during a single day, — we find it a rather hopeless mixture. Our lawn-sprinkler obeys the third law of motion, while our pleasure in possessing it is a fact for psychology; the preparation of our food is an applied chemistry, its adulteration depends upon economic conditions, and its effect upon health is a matter of physiology; our manner of speech is governed by phonetic laws, while the things we say reflect the moral standards of the time: in a word, one science seems to run into another science as chance may decide, without order or distinction. If, however, we look over the world as a whole, or examine historically any long period of human existence, the survey is less bewildering. The world of nature breaks up at once, as we inspect it, into living objects, the objects that change by growth, and non-living objects, the objects that change only by decay. And living objects divide, again, into objects that grow in one place, the plants, and objects that move about as they grow, the animals. Here, almost at the first glance, we have distinguished the raw materials of three different sciences: geology, botany, zoology. Now let us turn to some stage of human evolution: we may choose the social life of mankind before the dawn of civilisation. Primitive man was required, by the necessities of his case, to make himself weapons; to hunt animals for

food; to protect himself by clothing and shelter, and to avoid eating or drinking from poisonous or tainted sources. If he ventured upon the water, he must steer his course by the stars; if he banded with his fellows, he must hold to the code of honour of the tribe. He dreamed, and told his dreams; when he was glad, or angry, or afraid, he showed his feeling in gesture or by the expression of his face. Doubtless, his daily experience, if he ever thought about it, seemed to him as chaotic as our own has just appeared to us. But we, who have a larger vision of that experience, can see that it contained the natural germs of many sciences: mechanics, zoology and physiology, — astronomy, ethics and psychology.

We are thus led to the conclusion that the world of human experience is not altogether confused and disorderly. It shows lines of cleavage; to a certain extent, it arranges itself for us; so that the raw materials or the natural germs of what, in the higher forms of civilisation, become the separate sciences force themselves separately upon the attention. But we have not, as yet, anything more than raw materials. Science appears only when some man, taking the hint from nature, deliberately follows up a special line of enquiry throughout the whole of experience. Bridges and dwellings and weapons and furniture and tools and utensils were made long before there was a science of mechanics. The science begins when men begin to interpret the universe in mechanical terms, when the world at large is looked upon as a vast machine, working precisely as a tool or an engine works. Dreams, and the phenomena of trance, and the movements which express emotion were observed long before there was a science of psychology. The science begins when

men begin to interpret the universe in psychological terms, when the world at large is looked upon as mind, as a body of experience subject to psychological laws. In a word, every science takes up a certain attitude towards the world of human experience, or regards it from a definite point of view, and it is the business of a science to describe the world as it appears after the attitude has been taken up or the point of view adopted. What differentiates the sciences is just this difference of human interest; and what holds a science together, and brings its observations into relation, is just the fact that all the work has been done under the guidance of the same principles and from the same point of view.

We have now answered some of our general questions. Experience, we have seen, presents itself under different aspects. The differences are roughly outlined, but are definite enough to serve as a starting-point. These different aspects engage the attention of different men. Division of labour is necessary, if the whole of experience is to be brought within the sphere of science; and men's interests are so various that every aspect of experience is sure, in the long run, to find a student. As scientific investigation proceeds, and as the number of scientific men increases, more and more aspects of experience are revealed, and the sciences multiply. They do not exist independently, side by side, as accounts of separate portions of the world or of separate regions of experience; they overlap and coincide, describing one and the same world of experience as it appears from their special standpoints. They are not like blocks of knowledge, which when cut to the proper size and properly fitted together will give us a map of the universe; they are rather like the successive chapters of a

book which discusses a large topic from every possible point of view. Some chapters are long, and some are short; some are general, and some are special: this depends upon the sort of attitude which a given science takes towards experience. But all the chapters, or sciences, deal with the same world under its various aspects. —

We have still to enquire what science means by a law, and why it is that the advance of science depends upon the establishment of laws. The answer is simple. The longer scientific observations are continued, and the more scientific methods are refined, the clearer does it become that experience is regular and orderly. If only the conditions of an occurrence remain the same, the occurrence will always take place in the same way. A scientific law thus expresses a regularity, an unbroken uniformity, of some aspect of experience. Go to a dictionary, and look up Charles' law, and Grimm's law, and Weber's law: you will find that in all three cases — physics, philology, psychology — the laws are of this sort.

The formulation of a scientific law, therefore, means the final writing of some paragraph in some chapter of that book of the world which contains all the different sciences. No science is as yet complete: but the formulation of a law means that the science of which it holds is complete up to a certain point. The law embraces, covers, summarises a large body of observations, and also serves as a point of departure for the making of fresh observations. This is why the important dates in the history of science are the years in which scientific laws were established, and why the most honoured names in science are the names of the men who established them. It would, perhaps, make the study of science easier for the beginner if all proper names were

omitted, and we ceased to speak of the principle of Archimedes, and Euclidean geometry, and Newton's laws of motion. But these terms serve a good purpose : they show the importance of scientific laws, and they also reinforce a conclusion at which we have already arrived, — that what differentiates the sciences is the difference of human interests, and that what makes a science is some man's consistent adherence to a definite point of view.

§ 2. **The Subject-matter of Psychology.** — If it is true that all the sciences have the same sort of subject-matter, there can be no essential difference between the raw materials of physics and the raw materials of psychology. Matter and mind, as we call them, must be fundamentally the same thing. Let us find out, now, whether this statement is really as paradoxical as at first thought it appears.

All human knowledge is derived from human experience; there is no other source of knowledge. But human experience, as we have seen, may be considered from different points of view. Suppose that we take two points of view, as far as possible apart, and discover for ourselves what experience looks like in the two cases. First, we will regard experience as altogether independent of any particular person; we will assume that it goes on whether or not anyone is there to have it. Secondly, we will regard experience as altogether dependent upon the particular person; we will assume that it goes on only when someone is there to have it. We shall hardly find standpoints more diverse. What are the differences in experience, as viewed from them?

Take, to begin with, the three things that you first learn

about in physics: space, time and mass. Physical space, which is the space of geometry and astronomy and geology, is constant, always and everywhere the same. Its unit is 1 cm., and the cm. has precisely the same value wherever and whenever it is applied. Physical time is similarly constant; and its constant unit is the 1 sec. Physical mass is constant; its unit, the 1 gr., is always and everywhere the same. Here we have experience of space, time and mass considered as independent of the person who experiences them. Change, then, to the point of view which brings the experiencing person into account. The two vertical lines in Fig. 1 are physically equal; they measure alike in units of 1 cm. To you, who see them, they are not equal. The hour that you spend in the waiting-room of a village station and the hour that you spend in watching an amusing play are physically equal; they measure alike in units of 1 sec. To you, the one hour goes slowly, the other quickly; they are not equal. Take two circular cardboard boxes of different diameter (say, 2 cm. and 8 cm.), and pour sand into them until they both weigh, say, 50 gr. The two masses are physically equal; placed on the pans of a balance, they will hold the beam level. To you, as you lift them in your two hands, or raise them in turn by the same hand, the box of smaller diameter is considerably the heavier. Here we have experience of space, time and mass considered as dependent upon the experiencing person. It is the same experience that we were discussing just now. But our first point of view

FIG. 1.

gives us facts and laws of physics; our second gives us facts and laws of psychology.

Now take three other topics that are discussed in the physical text-books: heat, sound and light. Heat proper, the physicists tell us, is the energy of molecular motion; that is to say, heat is a form of energy due to a movement of the particles of a body among themselves. Radiant heat belongs, with light, to what is called radiant energy, —energy that is propagated by wave-movements of the luminiferous ether with which space is filled. Sound is a form of energy due to the vibratory movements of bodies, and is propagated by wave-movements of some elastic medium, solid, liquid or gaseous. In brief, heat is a dance of molecules; light is a wave-motion of the ether; sound is a wave-motion of the air. The world of physics, in which these types of experience are considered as independent of the experiencing person, is neither warm nor cold, neither dark nor light, neither silent nor noisy. It is only when the experiences are considered as dependent upon some person that we have warmth and cold, blacks and whites and colours and greys, tones and hisses and thuds. And these things are subject-matter of psychology.

We find, then, a great difference in the aspect of experience, according as it is viewed from the one or the other of our different standpoints. It is the same experience all through; physics and psychology deal with the same stuff, the same material; the sciences are separated simply — and sufficiently — by their point of view. From the standpoint of physics, we get such sciences as physics (in the narrower sense), chemistry, geology, astronomy, meteorology. From the standpoint of psychology we get, in the

same way, a special group of sciences: their names and provinces are given in § 7.

It must be clearly understood that we are not here attempting to give a strict definition of the subject-matter of psychology. We assume that everybody knows, at first hand, what human experience is, and we then seek to mark off the two aspects of this experience which are dealt with respectively by physics and psychology. Any further definition of the subject-matter of psychology is impossible. Unless one knows, by experience itself, what experience is, one can no more give a meaning to the term 'mind' than a stone can give a meaning to the term 'matter.'

§ 3. **The Common-sense View of Mind.** — If, before you read the two preceding sections, you had been asked to define psychology, you would probably have said, without hesitation, that it is the science of mind. But you would have meant by mind something that, at all events in appearance, is very different from the meaning that these two sections have given it. Let us see how nearly we can reconcile the common-sense idea of mind with the view that it is the sum-total of human experience considered as dependent upon the experiencing person.

The common-sense idea of the world is roughly this. The world is made up of, or contains, two radically different things: matter and mind. Matter is found in the physical objects around us; it always fills space; it is governed by mechanical laws, laws of cause and effect. Mind is found in ourselves and, very likely, in some of the other animals; it is immaterial, not spatial; it is not bound by mechanical laws, but is free to act as it will; if it submits to laws at all (as, for instance, to the laws of thought in our processes of reasoning), these are laws peculiar to it, and are not the same as the laws of nature. Nevertheless,

different as mind and matter are, they are joined together, in a very intimate way, both in ourselves and in such of the animals as possess minds; for our physical bodies are material. And when they are thus joined together, they act upon each other, mind affecting matter and matter affecting mind. We cry because we are grieved; we cannot think clearly because we have eaten too heavy a dinner.

Compare these statements, now, with the statements of §§ 1 and 2. Common sense declares that mind and matter are radically different. We have said that, in order to get the subject-matter of physics and of psychology, one must regard human experience from standpoints as diverse as can be found. So far there is a general agreement. Common sense declares that the laws of matter are different from the laws of mind. We have seen that, for instance, space, time and mass behave very differently, according as they are taken to be independent of, or dependent upon, the experiencing person. Again there is agreement. Common sense declares that we, and perhaps the animals, are made up both of matter and of mind. Here also, if we go beneath the difference of terms, there is agreement. The living body, as it is treated in the science of physiology, is treated from the physical point of view; it belongs to the independent aspect of experience. The same living body — that is to say, an organism, an organised individual — is, however, precisely the 'experiencing person' referred to in our definition of mind. It is when heat-waves strike the skin, and sound-waves strike the ear, and light-waves strike the eye, that we have experience in its dependent aspect, as warmth and tone and colour. On these three points, therefore, we have no serious quarrel with common sense.

On the other hand, common sense makes certain other

statements that we cannot accept. These statements all point to a view of mind which is not often expressed outright, in so many words, but which is very generally held: the view, namely, that mind is a living being, with all the qualities and powers that are possessed by material living beings; an immaterial animal, so to say, that dwells within the material animal; an inward man, manifesting itself in the behaviour of the outward man. A mind so conceived cannot fill space, because it is not material; but it has all the other properties of a living creature. It is free to act as it pleases, just as you are free to come or to go, to do this or to do that. It can influence the body, and be influenced by the body, just as you may influence or be influenced by your friend. This view of mind probably appears natural enough, although, as soon as you begin to ask questions, you will find that it is by no means clear. Natural or not, however, it is a view which we must here reject, for the following reasons.

(1) A statement that rests upon common sense is not likely to be argued; it is taken for granted, as something that needs no discussion. Yet, in theoretical matters, common sense is an unsafe guide. For the common sense of our own generation simply sums up so much of the advanced thought of former generations as the great body of mankind has found acceptable and intelligible. A brilliant speculation of one age may become the common sense of the next: but this does not make it any the less speculation, while in the course of becoming common sense its logical structure has, inevitably, been more or less damaged. Common sense, in theoretical matters, is past philosophy; and the philosophy is the more vulgarised, the farther it has travelled from its source.

There is no dispute as to the philosophical source from which, in the present instance, our common-sense ideas are derived. The view of mind and matter which we are now criticising was set forth, in all essential points, by the French philosopher, René Descartes (1596–1650). No doubt, the common-sense version has certain crude elements which are indefinitely older than Descartes; no doubt, also, it has been tinged by later thought, notably by the doctrine of organic evolution. In the main, however, what is common sense to-day was high Cartesian philosophy two centuries and a half ago.[1]

Plainly, then, we cannot take common sense for granted. As we should not nowadays pin our philosophical faith to Descartes, so we cannot leave Cartesian doctrines unquestioned when they appear in the garb of common sense. We shall rather expect to find that Descartes, and with him our own common sense, are partly right and partly wrong.

(2) That some of the doctrines of common sense agree, in general, with the position of §§ 1 and 2 has already been shown. The remainder must be rejected, because the evidence is against them. We are told that mind is not spatial: yet, as Fig. 1 shows, mental experience takes on the spatial form as readily as physical experience. We are told that mind is free to act as it pleases: yet, as we shall see in this book, the more carefully mind is studied, the more plainly are the laws of mental experience revealed. We are told that mind influences body, and

[1] You will find that this statement is borne out by the histories of philosophy. Turn, for instance, to A. K. Rogers, *A Student's History of Philosophy*, 1901, pp. 269–289, especially 284–287. The passage is not easy reading; but you will understand it well enough to see that what is said in the text is historically correct.

body mind. How an immaterial thing can influence and be influenced by a material thing we are not told, — for the very good reason that nobody knows: though, if this were the only view that did justice to the facts, we should nevertheless be bound to accept it. Since, as the following section shows, all the observed facts can be rationally explained from the standpoint of §§ 1 and 2, this standpoint must be preferred.

§ 4. **Psychophysical Parallelism.** — Common sense says that we cry because we are sorry, laugh because we are amused, run because we are frightened; that we feel gloomy and morose because we do not digest our food, go insane from softening of the brain, lose consciousness because we have inhaled ether. Mind influences body, and body influences mind. Our own position has been that mind and body, the subject-matter of psychology and the subject-matter of physiology, are simply two aspects of the same world of experience. They cannot influence each other, because they are not separate and independent things. For the same reason, however, wherever the two aspects appear, any change that occurs in the one will be accompanied by a corresponding change in the other. Your view of a town from the east cannot influence your view of the same town from the west; but as your view from the east differs in sunlight and moonlight, so correspondingly will your view from the west differ. This doctrine of the relation of mind to body is known as the doctrine of psychophysical parallelism: the common-sense doctrine is that of interaction.

From the point of view of psychophysical parallelism, then, it is not strictly true to say that we cry because we

are sorry. If we look at the whole experience under its independent aspect, we find that certain physical events, certain stimuli, affect the body; they set up in the body, and especially in the nervous system, certain physical changes; these changes cause the secretion of tears. This is an exhaustive account of the experience, considered as independent of the experiencing person. If we look at the experience under its dependent aspect, we find that our consciousness has been invaded by grief or remorse or some kindred emotion. The two sets of events, physical and mental, are parallel, but they do not interfere with each other. And the same thing holds of all the other cases cited at the beginning of this section.

By accepting this doctrine of parallelism we gain a two-fold advantage. On the positive side, we are able to do justice to all the observed facts; we never come into contradiction with facts. On the negative side, we avoid perplexing questions, questions that lead nowhere because they are put from a wrong standpoint. The common-sense view of mind appears natural; but as soon as you ask questions, you find it obscure. Where, for instance, on that view, does the body end and the mind begin? Do the senses belong to mind or to body? Is the mind always active and the body always passive? Do body and mind ever act independently of each other? Questions such as these arise at once; but it is a hard matter to answer them. Parallelism has no logical pitfalls of this kind.

At the same time, we need not be pedantic, and change our manner of speech to accord with the strict letter of parallelism. The astronomer does not scruple to talk, with all the rest of us, about sunrise and sunset. It is not strictly

true to say that we cry because we are sorry; our crying is the effect of certain nervous (that is, physical) changes, whose parallel on the mental side is the emotion of grief. But this parallel is constant and invariable. We should not cry, under the circumstances, unless we were sorry, because our sorrow is the mental aspect of those nervous changes that make us cry: we have only to shift our point of view, and what appeared as nervous change appears as emotion. So that, for all practical purposes, it is true to say that we cry because we are sorry, and run because we are frightened, and so forth. What we have to guard against is not the phrasing of these statements, but their popular interpretation. To suppose that the sorrow and the fear are literally the cause of tears and bodily movements would be on a par with supposing that the idea of watering the lawn can, literally and directly, turn the tap and set the sprinkler in motion.

§ 5. **Mental Process, Consciousness and Mind.** — The most striking fact about the world of human experience is the fact of change. Nothing stands still; everything goes on. The sun will someday lose its heat; the eternal hills are, little by little, breaking up and wearing away. Whatever we observe, and from whatever standpoint we observe it, we find process, occurrence; nowhere is there permanence or stability. Mankind, it is true, has sought to arrest this flux, and to give stability to the world of experience, by assuming two permanent substances, matter and mind: the occurrences of the physical world are then supposed to be manifestations of matter, and the occurrences of the mental world to be manifestations of mind. Such an hypothesis may be of value at a certain stage of human

thought; but every hypothesis that does not accord with the facts must, sooner or later, be given up. Physicists are therefore giving up the hypothesis of an unchanging, substantial matter, and psychologists are giving up the hypothesis of an unchanging, substantial mind. Stable objects and substantial things belong, not to the world of science, physical or psychological, but only to the world of common sense.

We have defined mind as the sum-total of human experience considered as dependent upon the experiencing person. We have said, further, that the phrase 'experiencing person' means the living body, the organised individual; and we have hinted that, for psychological purposes, the living body may be reduced to the nervous system and its attachments. Mind thus becomes the sum-total of human experience considered as dependent upon a nervous system. And since human experience is always process, occurrence, and the dependent aspect of human experience is its mental aspect, we may say, more shortly, that mind is the sum-total of mental processes. All these words are significant. 'Sum-total' implies that we are concerned with the whole world of experience, not with a limited portion of it; 'mental' implies that we are concerned with experience under its dependent aspect, as conditioned by a nervous system; and 'processes' implies that our subject-matter is a stream, a perpetual flux, and not a collection of unchanging objects.

It is not easy, even with the best will possible, to shift from the common-sense to the scientific view of mind; the change cannot be made all in a moment. We are to regard mind as a stream of processes? But mind is personal, my mind; and my personality continues throughout my life. The experiencing person is only the bodily organism? But, again, experience is personal, the

experience of a permanent self. Mind is spatial, just as matter is? But mind is invisible, intangible; it is not here or there, square or round.

These objections cannot be finally met until we have gone some distance into psychology, and can see how the scientific view of mind works out. Even now, however, they will weaken as you look at them. Face that question of personality. Is your life, as a matter of fact, always personal? Do you not, time and again, forget yourself, lose yourself, disregard yourself, neglect yourself, contradict yourself, in a very literal sense? Surely, the mental life is only intermittently personal. And is your personality, when it is realised, unchanging? Are you the same self in childhood and manhood, in your working and in your playing moods, when you are on your best behaviour and when you are freed from restraint? Surely, the self-experience is not only intermittent, but also composed, at different times, of very different factors. As to the other question: mind is, of course, invisible, because sight is mind; and mind is intangible, because touch is mind. Sight-experience and touch-experience are dependent upon the experiencing person. But common sense itself bears witness, against its own belief, to the fact that mind is spatial: we speak, and speak correctly, of an idea in our head, a pain in our foot. And if the idea is the idea of a circle seen in the mind's eye, it is round; and if it is the visual idea of a square, it is square.

Consciousness, as reference to any dictionary will show, is a term that has many meanings. Here it is, perhaps, enough to distinguish two principal uses of the word.

In its first sense, consciousness means the mind's awareness of its own processes. Just as, from the common-sense point of view, mind is that inner self which thinks, remembers, chooses, reasons, directs the movements of the body, so is consciousness the inner knowledge of this thought and government. You are conscious of the correctness of your answer to an examination question, of

the awkwardness of your movements, of the purity of your motives. Consciousness is thus something more than mind; it is "the perception of what passes in a man's own mind";[1] it is "the immediate knowledge which the mind has of its sensations and thoughts."[2]

In its second sense, consciousness is identified with mind, and 'conscious' with 'mental.' So long as mental processes are going on, consciousness is present; as soon as mental processes are in abeyance, unconsciousness sets in. "To say I am conscious of a feeling, is merely to say that I feel it. To have a feeling is to be conscious; and to be conscious is to have a feeling. To be conscious of the prick of the pin, is merely to have the sensation. And though I have these various modes of naming my sensation, by saying, I feel the prick of a pin, I feel the pain of a prick, I have the sensation of a prick, I have the feeling of a prick, I am conscious of the feeling; the thing named in all these various ways is one and the same."[3]

The first of these definitions we must reject. It is not only unnecessary, but it is also misleading, to speak of consciousness as the mind's awareness of itself. The usage is unnecessary, because, as we shall see later, this awareness is a matter of observation of the same general kind as observation of the external world; it is misleading, because it suggests that mind is a personal being, instead of a stream of processes. We shall therefore

[1] John Locke, *An Essay Concerning Human Understanding*, [1690] Bk. II., Ch. i., § 19.

[2] Dugald Stewart, *Outlines of Moral Philosophy*, [1793] Pt. I., Section i., § 7.

[3] James Mill, *Analysis of the Phenomena of the Human Mind*, [1829] Vol. I., Ch. v. Mill uses the word 'feeling' to denote what we have called 'mental process.'

take mind and consciousness to mean the same thing. But as we have the two different words, and it is convenient to make some distinction between them, we shall speak of mind when we mean the sum-total of mental processes occurring in the life-time of an individual, and we shall speak of consciousness when we mean the sum-total of mental processes occurring *now*, at any given 'present' time. Consciousness will thus be a section, a division, of the mind-stream. This distinction is, indeed, already made in common speech: when we say that a man has 'lost consciousness,' we mean that the lapse is temporary, that the mental life will shortly be resumed; when we say that a man has 'lost his mind,' we mean — not, it is true, that mind has altogether disappeared, but certainly that the derangement is permanent and chronic.

While, therefore, the subject-matter of psychology is mind, the direct object of psychological study is always a consciousness. In strictness, we can never observe the same consciousness twice over; the stream of mind flows on, never to return. Practically, we can observe a particular consciousness as often as we wish, since mental processes group themselves in the same way, show the same pattern of arrangement, whenever the organism is placed under the same circumstances. Yesterday's high tide will never recur, and yesterday's consciousnesses will never recur; but we have a science of psychology, as we have a science of oceanography.

§ 6. **The Method of Psychology.** — Scientific method may be summed up in the single word 'observation'; the only way to work in science is to observe those phenomena which form the subject-matter of science. And observa-

tion implies two things: attention to the phenomena, and record of the phenomena; that is, clear and vivid experience, and an account of the experience in words or formulas.

In order to secure clear experience and accurate report, science has recourse to experiment. An experiment is an observation that can be repeated, isolated and varied. The more frequently you can *repeat* an observation, the more likely are you to see clearly what is there and to describe accurately what you have seen. The more strictly you can *isolate* an observation, the easier does your task of observation become, and the less danger is there of your being led astray by irrelevant circumstances, or of placing emphasis on the wrong point. The more widely you can *vary* an observation, the more clearly will the uniformity of experience stand out, and the better is your chance of discovering laws. All experimental appliances, all laboratories and instruments, are provided and devised with this one end in view: that the student shall be able to repeat, isolate and vary his observations. —

The method of psychology, then, is observation. To distinguish it from the observation of physical science, which is inspection, a looking-at, psychological observation has been termed introspection, a looking-within. But this difference of name must not blind us to the essential likeness of the methods. Let us take some typical instances.

We may begin with two very simple cases. (1) Suppose that you are shown two paper discs: the one of an uniform violet, the other composed half of red and half of blue. If this second disc is rapidly rotated, the red and blue will mix, as we say, and you will see a certain blue-red, that is, a kind of violet. Your problem is, so to adjust the pro-

portions of red and blue in the second disc that the resulting violet exactly matches the violet of the first disc. You may repeat this set of observations as often as you like; you may isolate the observations by working in a room that is free from other, possibly disturbing colours; you may vary the observations by working to equality of the violets first from a two-colour disc that is distinctly too blue, and secondly from a disc that is distinctly too red. (2) Suppose, again, that the chord *c-e-g* is struck, and that you are asked to say how many tones it contains. You may repeat this observation; you may isolate it, by working in a quiet room; you may vary it, by having the chord struck at different parts of the scale, in different octaves.

It is clear that, in these instances, there is practically no difference between introspection and inspection. You are using the same method that you would use for counting the swings of a pendulum, or taking readings from a galvanometer scale, in the physical laboratory. There is a difference in subject-matter: the colours and the tones are dependent, not independent experiences: but the method is essentially the same.

Now let us take some cases in which the material of introspection is more complex. (1) Suppose that a word is called out to you, and that you are asked to observe the effect which this stimulus produces upon consciousness: how the word affects you, what ideas it calls up, and so forth. The observation may be repeated; it may be isolated, — you may be seated in a dark and silent room, free from disturbances; and it may be varied, — different words may be called out, the word may be flashed upon a screen instead of spoken, etc. Here, however, there seems

to be a difference between introspection and inspection. The observer who is watching the course of a chemical reaction, or the movements of some microscopical creature, can jot down from moment to moment the different phases of the observed phenomenon. But if you try to report the changes in consciousness, while these changes are in progress, you interfere with consciousness; your translation of the mental experience into words introduces new factors into that experience itself. (2) Suppose, again, that you are observing a feeling or an emotion: a feeling of disappointment or annoyance, an emotion of anger or chagrin. Experimental control is still possible; situations may be arranged, in the psychological laboratory, such that these feelings may be repeated, isolated and varied. But your observation of them interferes, even more seriously than before, with the course of consciousness. Cool consideration of an emotion is fatal to its very existence; your anger disappears, your disappointment evaporates, as you examine it.

To overcome this difficulty of the introspective method, students of psychology are usually recommended to delay their observation until the process to be described has run its course, and then to call it back and describe it from memory. Introspection thus becomes retrospection; introspective examination becomes *post mortem* examination. The rule is, no doubt, a good one for the beginner; and there are cases in which even the experienced psychologist will be wise to follow it. But it is by no means universal. For we must remember (*a*) that the observations in question may be repeated. There is, then, no reason why the observer to whom the word is called out, or in whom the emotion is set up, should not report at once upon the first

stage of his experience: upon the immediate effect of the word, upon the beginnings of the emotive process.[1] It is true that this report interrupts the observation. But, after the first stage has been accurately described, further observations may be taken, and the second, third and following stages similarly described; so that presently a complete report upon the whole experience is obtained. There is, in theory, some danger that the stages become artificially separated; consciousness is a flow, a process, and if we divide it up we run the risk of missing certain intermediate links. In practice, however, this danger has proved to be very small; and we may always have recourse to retrospection, and compare our partial results with our memory of the unbroken experience. Moreover, (*b*) the practised observer gets into an introspective habit, has the introspective attitude ingrained in his system; so that it is possible for him, not only to take mental notes while the observation is in progress, without interfering with consciousness, but even to jot down written notes, as the histologist does while his eye is still held to the ocular of the microscope.

In principle, then, introspection is very like inspection. The objects of observation are different; they are objects of dependent, not of independent experience; they are likely to be transient, elusive, slippery. Sometimes they refuse to be observed while they are in passage; they must be preserved in memory, as a delicate tissue is pre-

[1] We discuss in § 69, where we are dealing with the elementary processes in emotion, the special difficulty mentioned above: that, if you concentrate your attention, say, upon your anger, the anger disappears. This difficulty makes it necessary to lay down special rules for the observation of emotion. But it does not make it necessary — and that is the point here — to observe emotion retrospectively.

served in hardening fluid, before they can be examined. And the standpoint of the observer is different; it is the standpoint of human life and of human interest, not of detachment and aloofness. But, in general, the method of psychology is much the same as the method of physics.

It must not be forgotten that, while the method of the physical and the psychological sciences is substantially the same, the subject-matter of these sciences is as different as it can well be. Ultimately, as we have seen, the subject-matter of all the sciences is the world of human experience; but we have also seen that the aspect of experience treated by physics is radically different from the aspect treated by psychology. The likeness of method may tempt us to slip from the one aspect to the other, as when a text-book of physics contains a chapter on vision and the sense of colour, or a text-book of physiology contains paragraphs on delusions of judgment; but this confusion of subject-matter must inevitably lead to confusion of thought. Since all the sciences are concerned with the one world of human experience, it is natural that scientific method, to whatever aspect of experience it is applied, should be in principle the same. On the other hand, when we have decided to examine some particular aspect of experience, it is necessary that we hold fast to that aspect, and do not shift our point of view as the enquiry proceeds. Hence it is a great advantage that we have the two terms, introspection and inspection, to denote observation taken from the different standpoints of psychology and of physics. The use of the word introspection is a constant reminder that we are working in psychology, that we are observing the dependent aspect of the world of experience.

Observation, as we said above, implies two things: attention to the phenomena, and record of the phenomena. The attention must be held at the highest possible degree of concentration; the record must be photographically accurate. Observation is, therefore, both difficult and fatiguing; and introspection is, on the whole, more difficult and more fatiguing than inspection. To

secure reliable results, we must be strictly impartial and unprejudiced, facing the facts as they come, ready to accept them as they are, not trying to fit them to any preconceived theory; and we must work only when our general disposition is favourable, when we are fresh and in good health, at ease in our surroundings, free from outside worry and anxiety. If these rules are not followed, no amount of experimenting will help us. The observer in the psychological laboratory is placed under the best possible external conditions; the room in which he works is fitted up and arranged in such a way that the observation may be repeated, that the process to be observed may stand out clearly upon the background of consciousness, and that the factors in the process may be separately varied. But all this care is of no avail, unless the observer himself comes to the work in an even frame of mind, gives it his full attention, and is able adequately to translate his experience into words.

§ 7. **The Scope of Psychology.** — If mind is the sum-total of human experience considered as dependent upon the experiencing person, it follows that each one of us can have direct acquaintance only with a single mind, namely, with his own. We are concerned in psychology with the whole world of human experience; but we are concerned with it solely under its dependent aspect, as conditioned by a nervous system; and a nervous system is a particular thing, possessed by a particular individual. In strictness, therefore, it is only his own mind, the experience dependent upon his own nervous system, that each of us knows at first-hand; it is only to this limited and individual subject-matter that the method of experimental introspection can be directly applied. How, then, is a scientific psychology possible? How can psychology be anything more than a body of personal beliefs and individual opinions?

The difficulty is more apparent than real. We have every reason to believe, not only in general that our neighbours have minds like our own, that is, are able like ourselves to view experience in its dependent aspect, but also in detail that human minds resemble one another precisely as human bodies do. Within a given race there is much apparent diversity of outward form: differences in height and figure, in colour of hair and eyes, in shape of nose and mouth. We notice these differences, because we are obliged in everyday life to distinguish the persons with whom we come in contact. But the resemblances are more fundamental than the differences. If we have recourse to exact measurements, we find that there is in every case a certain standard or type to which the individual more or less closely conforms and about which all the individuals are more or less closely grouped. And even without measurement we have evidence to the same effect: strangers see family likenesses which the members of the family cannot themselves detect, and the units in a crowd of aliens, Chinese or Negroes, look bewilderingly alike.

Now all of our main social institutions rest upon the assumption that the individuals of whom society is composed possess minds, and possess minds that are of the same sort. Language, religion, law and custom, — they one and all rest upon this assumption, and they one and all bear testimony that the assumption is well grounded. Would a man invent language in order to talk to himself? Language implies that there are more minds than one. And would the use of a common speech be possible if minds were not essentially alike? Men differ in their command of language, as they differ in complexion, or in

liability to disease; but the general use of language testifies to a fundamental likeness of mental constitution in us all.

Hence the psychologist is fully justified in believing that other men have minds of the same kind as his own, and in basing psychology upon the introspective reports furnished by a number of different observers. These reports show, in point of fact, just what we should expect them to show: a fundamental agreement, and a great variety of detail, — the mental differences grouping themselves, as we have seen that physical differences group themselves, about a central type or standard.

If, however, we attribute minds to other human beings, we have no right to deny them to the higher animals. These animals are provided with a nervous system of the same pattern as ours, and their conduct or behaviour, under circumstances that would arouse certain feelings in us, often seems to express, quite definitely, similar feelings in them. Surely we must grant that the highest vertebrates, mammals and birds, have minds. But the lower vertebrates, fishes and reptiles and amphibia, possess a nervous system of the same order, although of simpler construction. And many of the invertebrates, insects and spiders and crustaceans, show a fairly high degree of nervous development. Indeed, it is difficult to limit mind to the animals that possess even a rudimentary nervous system; for the creatures that rank still lower in the scale of life manage to do, without a nervous system, practically everything that their superiors do by its assistance. The range of mind thus appears to be as wide as the range of animal life.

The plants, on the other hand, appear to be mindless. Many of them are endowed with what we may term sense-organs, that is,

organs differentiated to receive certain forms of stimulus, pressure, impact, light, etc. These organs are analogous in structure to the sense-organs of the lower animal organisms: thus, plant 'eyes' have been found, which closely resemble rudimentary animal eyes, and which — if they belonged to animals — might mediate the perception of light: so that the development of the plant-world has evidently been governed by the same general laws of adaptation to environment that have been at work in the animal kingdom. But we have no evidence of a plant-consciousness.

Just as the scope of psychology extends beyond man to the animals, so does it extend from the individual man to groups of men, to societies. The subject-matter of psychology is human experience considered as dependent upon the individual. But since the individuals of the same race and epoch are organised in much the same way, and since they live together in a society where their conduct affects and is affected by the conduct of others, their view of experience under its dependent aspect naturally becomes, in certain main features, a common or general view; and this common view is embodied in those social institutions to which we have referred above, — in language, religion, law and custom. There is no such thing as a collective mind, or a national mind, or a social mind, if we mean by mind some immaterial being; but there is a collective mind, if we mean by it the sum-total of human experience considered as dependent upon a social group of similar individuals. The study of the collective mind gives us a psychology of language, a psychology of myth, a psychology of custom, etc.; it also gives us a differential psychology of the Latin mind, of the Anglo-Saxon mind, of the Oriental mind, etc.

And this is not all: the scope of psychology extends,

still further, from the normal to the abnormal mind. Life, as we know, need not be either complete or completely healthy life. The living organism may show defect, the lack of a limb or of a sense-organ; and it may show disorder and disease, a temporary or a permanent lapse from health. So it is with mind. The consciousnesses of those who are born deaf or blind are defective; they lack certain sensations and images that are normally present. In dreaming and the hypnotic state, during intoxication, after prolonged sleeplessness or severe strain of any kind, we have illustrations of temporary mental derangement. And the various forms of insanity — mania, melancholia, dementia — are forms of permanent mental disorder.

Derangement of the social mind may be studied in the various panics, fads, epidemics of speculation, of false belief, etc., which occur from time to time even in the most highly civilised societies. The mob consciousness stands to a healthy social consciousness very much as dreaming to the waking life. Permanent disorder of the social mind means the downfall of society.

All these various fields of psychology may be cultivated for their own sake, on account of their intrinsic interest and value; they must, indeed, be so cultivated, if psychology is to progress. At the same time, their facts and laws often throw light upon the problems of normal human psychology. Suppose, for instance, that a man, blind from his birth, is rendered able to see by a surgical operation. He must learn to use his eyes, as a child learns to walk. And the gradual perfecting of his vision, the mistakes and confusions to which he is liable, all the details of his visual education, form a storehouse of facts upon which the psychologist can draw when he seeks to illustrate the development of the perception of space in the normal mind, — the manner in which we come to judge of the distance of objects from ourselves

and from one another, of their direction, and of their size and shape. Instructive, also, are those forms of mental unsoundness which consist in the derangement of a single group of processes. The various types of morbid fear — agoraphobia, the fear of being alone in open spaces; neophobia, the fear of everything that is new; phobophobia, the nervous dread of being afraid — are only exaggerated forms of experiences that most of us have had. The sanest man will feel lost when he passes, suddenly, from a quiet country life to the bustle of a large town; we are all a little timid when we enter a strange community; we have all been afraid that on such-and-such an occasion we shall show our nervousness. Similarly, the self-importance of paranoia is merely an exaggeration of the pleased self-consciousness, the self-complacency, that we often observe in others and, if we are honest, must often detect in ourselves. In all these instances, the strong lines of the caricature may help us to a more correct picture of the normal consciousness.

§ 8. **The Use of Analogy in Psychology.** — We have agreed that the psychologist is not confined to a knowledge of his own mind. Although this is the only mind to which he can directly apply the method of experimental introspection, he can apply the method indirectly to any number of minds. Psychology is based upon the introspections of a large number of trained observers.

But we have gone much farther than this. We have spoken of an animal psychology, a social psychology, and a psychology of the abnormal mind. What, then, is the method to be employed in these branches of psychology? We cannot ask the animal or the society or the madman to introspect!

Yet, in a sense, this is just what we do. Observation, it will be remembered, implies two things: attention to the phenomena, and record of the phenomena. We

ourselves record mental phenomena, for psychological purposes, in language. This form of record has great advantages: it is flexible, since we have a large vocabulary at our disposal; it is constant, since written or printed reports may be preserved for a long time; and it is easily intelligible, since we are accustomed to the use of words in everyday life. At the same time, language is not the only possible means of expression. Physically regarded, it is a complex bodily movement: spoken language is a movement of the larynx, written language a movement of the hand: and it belongs to the class of movements that we term gestures. We can express our ideas by a grimace or a shrug of the shoulders, as well as by spoken words or a written paragraph.

Now the psychologist argues, by analogy, that what holds of himself holds also, in principle, of the animal, of society, and of the insane. He argues that the movements of animals are, to a large extent, gestures; that they express or record the animal's mental processes. He therefore tries, so far as possible, to put himself in the place of the animal, to find the conditions under which his own movements would be of the same general kind; and then, from the character of his human consciousness, he attempts — always bearing in mind the limit of development of the animal's nervous system — to reconstruct the animal consciousness. He calls experiment to his assistance, and places the animal in circumstances which permit of the repetition, isolation and variation of certain types of movement or behaviour. The animal is thus made, so to say, to observe, to introspect; it attends to certain stimuli, and registers its experience by gesture. Of course, this is not scientific observation: science, as

we said in § 1, implies a definite attitude to the world of experience, and consists in a description of the world as viewed from a definite standpoint. None the less, it is observation, and as such furnishes raw material for science. The psychologist works the raw material into shape; he observes the gesture, and transcribes the animal consciousness in the light of his own introspection.

Roundabout as this method appears, it has nevertheless led, in the hands of skilled investigators, to perfectly definite results. And it is by way of detailed investigation, and by that way only, that the general questions of animal psychology can be finally answered. One of these questions is that of the 'criterion of mind.' How are we to decide whether the animal before us does or does not possess mind? How are we to decide whether it has attended to the stimulus, so that its movement is a gesture movement, or whether it has received the stimulus mindlessly and mechanically, so that the movement is a reflex? An answer now commonly given to this question is that we may assume the presence of mind wherever the animal rapidly adjusts itself to new conditions, quickly learns to get its bearings in a novel environment. The answer is, of course, based upon the analogy of human experience. It is, however, unwise to commit oneself to a criterion of this nature. What is needed is an exhaustive study of all the various modes in which animals do, as a matter of fact, adjust themselves to new conditions. Then the criterion of mind will appear, so to speak, of its own accord.

Another general question is that of the interpretation of the animal consciousness. Shall we assume that this consciousness is always as simple as possible? Or shall we give the animal the benefit of our doubt, take its different forms of behaviour at their face value, and ascribe to it processes of memory, of ideation, of reasoning, that differ from our own only in degree? On this question opinion is sharply divided. Both positions may be supported by the analogy of the human consciousness, since this may be, under very similar circumstances, either extremely com-

plex or surprisingly simple. And so we find one authority laying it down that "in no case may we interpret an action as the outcome of the exercise of a higher psychical faculty, if it can be interpreted as the outcome of the exercise of one which stands lower in the psychological scale";[1] while another authority declares that "we are too ready to adopt simple — unduly simple — explanations of the animals by which we are surrounded."[2] It is, again, unwise to commit oneself to either view. The animal must be subjected to experimental test, under conditions of gradually increasing complexity, and we must find out by actual trial how far it is able to cope with these conditions. Then our principles of interpretation will, also, emerge of their own accord. —

We do, then, make the animals attend to stimuli and report their experiences to us; we do, after a fashion, make them introspect. This would be impossible if introspection implied a reflective attitude towards mind, or a special kind of mental awareness of mental processes. But, as we have seen, introspection is simply observation of dependent experience: it is therefore precisely the sort of observation that an animal can make, if it has a mind at all. Our own task is to do what the animals cannot do: to systematise and interpret the observations in terms of human consciousness.

What holds of the study of the animal mind holds also of social psychology. The introspections made in common by the members of a social group are recorded for us in the forms of speech, in custom and law, in myth and religion. Society has introspected, and has recorded its introspections in these various institutions. It is, obviously, impossible for the psychologist to experiment upon the social mind in any direct way. It is therefore fortunate that nature has made experiments for him. By

[1] C. L. Morgan, *An Introduction to Comparative Psychology*, 1894, 53.

[2] W. Mills, *The Nature and Development of Animal Intelligence*, 1898, 12.

comparing the languages, customs, etc., of different types of human society at all the different levels of human evolution, he is able to repeat, isolate and vary his observations; history furnishes him with a laboratory of social psychology.

It is clear that the study of social psychology requires the use of analogy. It is we, the moderns, who study the myths and customs of primitive man, and we have to psychologise these myths and customs from our own modern standpoint. Hence it is natural to find, in works upon the subject, the same sort of disagreement on general principles that we have noted in the case of animal psychology. And the remedy is the same. We must not hastily adopt a particular view of human evolution, but must patiently examine all the available records; must seek to add to the records by researches among the lower races of mankind; and must then accept the general principles that an exhaustive survey of the facts suggests to us.

Since social psychology is thus a genetic study, a study of human development, it has become customary to speak of its method as a genetic method. In strictness, however, there is no such thing as a genetic method. There is a genetic point of view, as there is a static point of view. We may be interested in the sequence of mental processes, in tracing the course of mind from simple to complex; or we may be interested in the coexistence of mental processes, in unravelling the tangle of a special sort of consciousness. But the difference of interest does not mean a difference of method.

For the psychology of dreaming and of intoxication we have the advantage of direct introspective records. We may also have recourse to experiment. A sleeping person, for example, may be subjected to various kinds of stimulation, and may be aroused, after the stimuli have been applied, to give an account of the dream which they occasioned.

The psychological study of hypnosis is less direct, since the hypnotic subject usually forgets, on arousal, what has taken place during the hypnotic state. We must therefore observe his behaviour during hypnosis, taking care to make our tests as simple and straightforward as possible, and must then seek to reconstruct the hypnotic consciousness on the analogy of the normal waking consciousness. It is, of course, possible to secure introspective reports from hypnotic subjects; but it is still a matter of dispute whether these reports are true records of observations, or do not rather reflect the ideas and opinions of those who are conducting the experiment. The hypnotic subject is extremely suggestible; that is to say, he is exceedingly liable to pick up a hint from the experimenter, and to report as he thinks the experimenter desires or expects him to report.

For the study of the insane mind, we have, in the first place, the utterances and behaviour of insane persons. We have also the opportunity to experiment; the inmates of hospitals may be subjected to systematic tests, the results of which will give us an insight into their mental processes. So far, this branch of psychology is in a backward condition, since we have been more concerned to shelter and, if possible, to cure the insane than to describe the insane consciousness. Certain forms of insanity are, however, of great psychological interest, and we may look confidently to a realisation of this interest in the near future. —

After all, therefore, it is not so absurd as at first thought it seems, to say that we require the animal and society and the madman to introspect. All three may attend; all three may report their experiences. The attention is

likely to be partial, fitful, roving, and the report is likely to be transient, equivocal, imperfect; and so we are compelled, in all three cases, to fall back upon the analogy of our own consciousness. In other words, it is entirely possible to work out, by psychological method, a psychology of the animal, of the social, and of the unsound mind, but it is also very difficult: the psychologist is exposed, at every moment, to the danger of misinterpretation. However, here as elsewhere in science, the pursuit of knowledge furnishes its own corrective. Sooner or later the unfit hypothesis breaks down in face of newly discovered facts.

§ 9. **The Problem of Psychology.** — Science seeks always to answer three questions in regard to its subject-matter, the questions of what, how, and why. What precisely, stripped of all complications and reduced to its lowest terms, is this subject-matter? How, then, does it come to appear as it does; how are its elements combined and arranged? And, finally, why does it appear now in just this particular combination or arrangement? All three questions must be answered, if we are to have a science that shall satisfy the definition of § 1.

It is often said that the answers to the questions 'what' and 'how' give us a description, the answer to the question 'why' an explanation, of the facts with which science deals. This distinction is useful, if we do not make it too rigid. It would be a grave mistake to suppose, for instance, that we may first of all work out an exhaustive description of the world, and then proceed deliberately to explain what we have already described. On the contrary, knowledge grows by a constant give and take between description and explanation; we describe in terms of some theory, that is, in terms of some tentative explanation, and then we rectify

our theory in the light of the observed facts; and so on, over and over again. The distinction is thus logical only; it does not point to two successive stages in the history of the special sciences.

To answer the question 'what' is the task of analysis. Physical science, for example, tries by analysis to reduce the world of independent experience to its lowest terms, and so arrives at the various chemical elements. To answer the question 'how' is the task of synthesis. Physical science traces the behaviour of the elements in their various combinations, and presently succeeds in formulating the laws of nature. When these two questions have been answered, we have a description of physical phenomena. But science enquires, further, why a given set of phenomena occurs in just this given way, and not otherwise; and it answers the question 'why' by laying bare the cause of which the observed phenomena are the effect. There was dew on the ground last night because the surface of the earth was colder than the layer of air above it; dew forms on glass and not on metal because the radiating power of the one is great and of the other is small. When the cause of a physical phenomenon has thus been assigned, the phenomenon is said to be explained.

So far, now, as description is concerned, the problem of psychology closely resembles the problem of physics. The psychologist seeks, first of all, to analyse mental experience into its simplest components. He takes a particular consciousness and works over it again and again, phase by phase and process by process, until his analysis can go no further. He is left with certain mental processes which resist analysis, which are absolutely simple in

nature, which cannot be reduced, even in part, to other processes. This work is continued, with other consciousnesses, until he is able to pronounce with some confidence upon the nature and number of the elementary mental processes. Then he proceeds to the task of synthesis. He puts the elements together, under experimental conditions: first, perhaps, two elements of the same kind, then more of that kind, then elementary processes of diverse kinds: and he presently discerns that regularity and uniformity of occurrence which we have seen to be characteristic of all human experience. He thus learns to formulate the laws of connection of the elementary mental processes. If sensations of tone occur together, they blend or fuse; if sensations of colour occur side by side, they enhance one another: and all this takes place in a perfectly regular way, so that we can write out laws of tonal fusion and laws of colour contrast.

If, however, we attempted to work out a merely descriptive psychology, we should find that there was no hope in it of a true science of mind. A descriptive psychology would stand to scientific psychology very much as the old-fashioned natural histories stand to modern text-books of biology, or as the view of the world which a boy gets from his cabinet of physical experiments stands to the trained physicist's view. It would tell us a good deal about mind; it would include a large body of observed facts, which we might classify and, in large measure, bring under general laws. But there would be no unity or coherence in it; it would lack that single guiding principle which biology has, for instance, in the law of evolution, or physics in the law of the conservation of energy. In order to make psychology scientific we must not only describe,

we must also explain mind. We must answer the question 'why.'

But here is a difficulty. It is clear that we cannot regard one mental process as the cause of another mental process, if only for the reason that, with change of our surroundings, entirely new consciousnesses may be set up. When I visit Athens or Rome for the first time, I have experiences which are due, not to past consciousnesses, but to present stimuli. Nor can we, on the other hand, regard nervous processes as the cause of mental processes. The principle of psychophysical parallelism lays it down that the two sets of events, processes in the nervous system and mental processes, run their course side by side, in exact correspondence but without interference: they are, in ultimate fact, two different aspects of the same experience. The one cannot be the cause of the other.

Nevertheless, it is by reference to the body, to the nervous system and the organs attached to it, that we explain mental phenomena. The nervous system does not cause, but it does explain mind. It explains mind as the map of a country explains the fragmentary glimpses of hills and rivers and towns that we catch on our journey through it. In a word, reference to the nervous system introduces into psychology just that unity and coherence which a strictly descriptive psychology cannot achieve.

It is worth while, for the sake of clearness, to dwell on this point in more detail. The physical world, the world of independent experience, just because it is independent of the individual man, is complete and self-contained. All of the processes that make it up are bound together as cause and effect; nowhere is there a gap or break in their connection. Now, among the processes that make up this independent world are the processes

of the nervous system. These are linked, as cause and effect, both to one another and also to physical processes, outside the body, which precede and follow them; they have their fixed place in the unbroken chain of physical events; they may themselves be explained, exactly as the occurrence of dew is explained. Mental processes, on the other hand, correspond, not to the whole series of physical events, but only to a small part of them, namely, to certain events within the nervous system. It is natural, then, that mental phenomena should appear scrappy, disconnected, unsystematic. It is also natural that we should seek their explanation in the nervous processes which run parallel to them, and whose causal connection with all the other processes of the independent world ensures the continuity that they so conspicuously lack. Mind lapses every night, and reforms every morning; but the bodily processes go on, in sleep and in waking. An idea drops out of memory, to recur, perhaps quite unexpectedly, many years later; but the bodily processes have been going on without interruption. Reference to the body does not add one iota to the data of psychology, to the sum of introspections. It does furnish us with an explanatory principle for psychology; it does enable us to systematise our introspective data. Indeed, if we refuse to explain mind by body, we must accept the one or the other of two, equally unsatisfactory alternatives: we must either rest content with a simple description of mental experience, or must invent an unconscious mind to give coherence and continuity to the conscious. Both courses have been tried. But, if we take the first, we never arrive at a science of psychology; and if we take the second, we voluntarily leave the sphere of fact for the sphere of fiction.

These are scientific alternatives. Common sense, also, has in its own fashion realised the situation, and has found its own way out. It is precisely because of the incompleteness and disconnectedness of mental experience that common sense constructs a hybrid world, travelling easily from mental to physical and back again, filling up the breaks in the mental by material borrowed from the physical. That way, we may be sure, lies confusion of thought. The truth underlying the confusion is, however, the

implicit acknowledgment that the explanatory principle for psychology must be looked for beyond, and not within, the world of dependent experience.—

Physical science, then, explains by assigning a cause; mental science explains by reference to those nervous processes which correspond with the mental processes that are under observation. We may bring these two modes of explanation together, if we define explanation itself as the statement of the proximate circumstances or conditions under which the described phenomenon occurs. Dew is formed under the condition of a difference of temperature between the air and the ground; ideas are formed under the condition of certain processes in the nervous system. Fundamentally, the object and the manner of explanation, in the two cases, are one and the same.

In fine, just as the method of psychology is, on all essential points, the method of the natural sciences, so is the problem of psychology essentially of the same sort as the problem of physics. The psychologist answers the question 'what' by analysing mental experience into its elements. He answers the question 'how' by formulating the laws of connection of these elements. And he answers the question 'why' by explaining mental processes in terms of their parallel processes in the nervous system. His programme need not be carried out in this order: he may get the hint of a law before his analysis is completed, and the discovery of a sense-organ may suggest the occurrence of certain elementary processes before he has found these processes by introspection. The three questions are intimately related, and an answer to any one helps towards the answers to the other two. The measure of our progress in scientific psychology is our ability to return satisfactory answers to all three.

References for Further Reading[1]

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K. Pearson, *The Grammar of Science*, 1900, chs. i., iii.

§ 2. O. Kuelpe, *Outlines of Psychology*, 1909, § 1, 1–7.
W. Wundt, *Outlines of Psychology*, 1907, §§ 1, 2.

§ 3. G. S. Fullerton, *A System of Metaphysics*, 1904, chs. i., v.

§ 4. W. James, *Principles of Psychology*, i., 1890, 128–144 (for interaction: read with E. B. Titchener, *Were the Earliest Organic Movements Conscious or Unconscious?* in *Popular Science Monthly*, lx., 1901–2, 458–469).
H. Ebbinghaus, *Grundzüge der Psychologie*, i., 1905, § 4 (for parallelism).
C. A. Strong, *Why the Mind has a Body*, 1903, 67–160.
G. S. Fullerton, *Is Man an Automaton?* in *Popular Science Monthly*, lxx., 1907, 149–156.

§ 5. For the character of mind as process, see W. Wundt, *Philosophische Studien*, x., 1894, 121–124.

§ 6. On observation and experiment, see W. S. Jevons, *The Principles of Science*, 1900, Bk. iv., chs. xviii., xix.
On introspection, see G. Spiller, *The Mind of Man*, 1902, 15–20, 34–37; W. B. Pillsbury, *A Suggestion toward a Reinterpretation of Introspection*, in *Journal of Philosophy, Psychology and Scientific Methods*, i., 1904, 225–228.

§ 7. W. Wundt, *Outlines of Psychology*, 1907, §§ 19–21.
R. M. Yerkes, *Animal Psychology and Criteria of the Psychic*, in *Journal of Philosophy, Psychology and Scientific Methods*, ii., 1905, 141–149.
G. T. W. Patrick, *The Psychology of Football*, in *American Journal of Psychology*, xiv., 1903, 368–381.

[1] The works cited under this heading throughout the book are of various degrees of difficulty, and their point of view is in many cases opposed to that of the author. To avoid confusion of thought, the student is advised to refer to them only after he has read the book through, and has thus formed a clear idea of the psychological system which it outlines. Difficulties and contradictions will then seem less formidable and less vital than they would if encountered at the beginning of his study of mind.

The dates given are those of current editions. Works that have passed through a number of editions are, however, quoted by chapter and section rather than by page, so that earlier editions may be used.

T. Heller, *Studien zur Blinden-Psychologie*, in *Philosophische Studien*, xi., 1895, 226–253; 406–470; 531–562.

§ 8. C. L. Morgan, *An Introduction to Comparative Psychology*, 1894, 37–47.

W. Wundt, *Völkerpsychologie*, i., 1904, Einleitung; also *Sprachgeschichte und Sprachpsychologie*, 1901, § 1.

M. F. Washburn, *The Animal Mind, a Text-book of Comparative Psychology*, 1908, chs. i., ii.

§ 9. O. Kuelpe, *Introduction to Philosophy*, 1897, *Psychology*, 55–67.

W. James, *Principles of Psychology*, i., 1890, 1–4.

H. Münsterberg, *Psychology and Life*, 1899: essay on *Psychology and Physiology*, 35–99.

NOTE ON THE CLASSIFICATION OF PSYCHOLOGY

The following list of the various subdivisions of psychology is made out on the basis of the distinctions drawn in § 7. We cannot hope to make the list final and complete. But it is well to realise, at the beginning of one's study of mind, how wide and varied is the territory that psychology covers.

I. Psychology of the Normal Mind

A. Individual psychology

i. *Human psychology*. This may be subdivided into:

1. *General psychology*, or the psychology of the adult civilised man. This is the principal topic of the text-books of psychology: see, for instance, W. James, *Principles of Psychology*, 1890; J. Sully, *The Human Mind*, 1892.
2. *Special psychology*, or the psychology of the human mind in some other stage than that of adult manhood. Special psychology thus includes infant psychology, child psychology, the psychology of adolescence, the psychology of senility, etc. These psychologies are often written from the genetic point of view. — W. Preyer, *The Mind of the Child*, 1888–9 [*Die Seele des Kindes*, 1900]; G. S. Hall, *Adolescence*, 1904.
3. *Differential psychology*, or the study of the differences between individual minds. The minds compared may belong to persons of the same race, class, age, sex, etc., or to persons who differ in these respects. — L. W. Stern, *Ueber Psychologie der*

individuellen Differenzen, 1900; A. Binet, *L'Étude expérimentale de l'intelligence*, 1903.

4. *Genetic psychology*, which seeks to trace the development of mind from infancy to manhood, and its gradual decay in old age. — J. M. Baldwin, *Mental Development in the Child and the Race*, 1906.

ii. *Animal psychology.* This may be subdivided, like human psychology, into general, special, differential and genetic psychology. Since the workers in the field of animal psychology have, for the most part, been interested in the problems of mental evolution, animal psychology as a whole is often termed genetic psychology: but this is a misnomer. — E. Thorndike, *Animal Intelligence*, 1898; H. S. Jennings, *Behaviour of the Lower Organisms*, 1906.

iii. *Comparative psychology.* This is the comparative study, either of various types of animal mind, or of the minds of the animals and of man. It may be general, special or genetic. Like animal psychology, and for the same reason, it is often termed genetic psychology. — C. L. Morgan, *An Introduction to Comparative Psychology*, 1894; W. Wundt, *Lectures on Human and Animal Psychology*, 1896 [*Vorlesungen über die Menschen- und Thierseele*, 1906]; M. F. Washburn, *The Animal Mind*, 1908.

B. Collective psychology

The divisions of this department of psychology are not as yet sharply defined. We may, however, distinguish:

i. *Social psychology*, which includes the study of the social consciousness, and also the study of the products of the collective mind: language, law and custom, myth and religion. — G. Tarde, *Social Laws*, 1899; J. M. Baldwin, *Social and Ethical Interpretations in Mental Development*, 1906; W. Wundt, *Völkerpsychologie*, 1904–8.

ii. *Ethnic psychology*, the differential psychology of nations or races. — G. le Bon, *The Psychology of Peoples*, 1898; W. H. R. Rivers and C. S. Myers, *Cambridge Anthropological Expedition to Torres Straits*, 1901–3.

iii. *Class psychology*, the differential psychology of classes, professions, etc. — E. Tardieu, *Psychologie militaire*, 1898; L. Dauriac, *Essai sur l'esprit musical*, 1904.

II. Psychology of the Abnormal Mind

A. Individual psychology

i. *Psychology of deficient and exceptional minds.* — M. Howe and F. H. Hall, *Laura Bridgman*, 1903; C. Lombroso, *The Man of Genius*, 1891 [*L' uomo di genio*, 1894].

ii. *Psychology of mental derangement*, the study of temporary abnormalities of mind. — A. Maury, *Le sommeil et les rêves*, 1878; A. Moll, *Hypnotism*, 1890; E. Parish, *Hallucinations and Illusions*, 1897; S. de Sanctis, *I sogni*, 1899.

iii. *Psychology of mental disorder*, the study of the permanently deranged mind. — T. Ribot, *Diseases of Personality*, 1895; G. Störring, *Mental Pathology in its Relation to Normal Psychology*, 1907.

B. Collective psychology

Psychology of mental derangement. — J. Jastrow, *Fact and Fable in Psychology*, 1900; S. Sighele, *La foule criminelle*, 1901.

SENSATION

§ 10. **The Elementary Mental Processes.** — It is very important that we make no mistake as regards the nature and number of the elementary mental processes. For these elements are the simple materials out of which we are to build up our entire psychology. They must, therefore, be various enough and numerous enough to give rise, by their connections, to all the complicated phases of the human mind: to thought and sentiment, to memory and imagination, to emotion and perception. On the other hand, they must be strictly elementary; they must remain unchanged, however persistent our attempt at analysis and however refined our method of investigation. If the list is not complete, we shall be forced presently to smuggle in new elements: and that means bad logic and bad science. If we now pass as elementary any process that is really complex, we are guilty of a sheer blunder, and shall pay for it later on.

Here, however, is a dilemma. The science of psychology is still in the making; and, until it is rounded out and finished off, no final list of the mental elements can possibly be drawn up. We must make a decision in the matter; but we must not be dogmatic: we must stand ready to modify our decision, if the results of future research prove us to be wrong. Such a state of affairs is, perhaps, a little discouraging, since a right choice of elements is of cardinal importance; but it is not unnatural, nor is it dis-

creditable to psychology. All scientific problems require time for their solution; and this problem of the nature and number of the mental elements is comparatively new, — certainly not older than the middle of the last century. So long as mind was looked upon as a substance, a real being, a personal creature, psychology had no more to do than to note down the different powers or faculties or capacities of the mind, as they fell under observation. The list always remained open. Not until mind is regarded as a stream of processes, whose flow is throughout obedient to psychological law, does the problem of analysis become insistent. Besides, this problem can be solved only by help of the experimental method; and the first laboratory of psychology was founded as late as 1879. It is not surprising, then, that psychologists should still disagree as to the mental elements. Every year sees the proposal of some fresh process as candidate for elementary rank; every year brings proof that one or other of the older candidates must, after careful scrutiny, be debarred from competition. And this back-and-forth movement will continue, we must suppose, for many years to come.

There is, nevertheless, beneath all these cross-currents of controversy, a fairly definite trend of psychological opinion in the matter of the elementary processes. The list that we adopt in this book is accepted by a large number of psychologists, and, as a working hypothesis, has so far proved adequate to the composition of the human mind. If it has to be changed in the future, we may be tolerably sure that the change will come by way of addition, and not of subtraction, so that our acceptance of it will give us nothing to unlearn. — We set to work upon the assumption that there are at most three classes of mental ele-

ments; that two of these may, without any hesitation, be considered as sub-classes under a single general heading, even if they may not be grouped outright in a single class; and that all three may, with some show of probability, be viewed as processes of the same ultimate type.

The three classes of elementary processes are known as sensations, images, and affections. Sensations are, of course, the characteristic elements of perceptions, of the sights and sounds and similar experiences due to our present surroundings. Images are, in just the same way, the characteristic elements of ideas, of the mental pictures that memory furnishes of past and imagination of future experience. Sensations and images are so much alike that they are not seldom confused; we shall discuss their relations in detail in § 61. Lastly, affections are the characteristic elements of emotions, of love and hate, joy and sorrow. At first sight, they appear to be essentially different from sensations and images, though a closer examination brings out a number of fundamental resemblances. We shall discuss them in § 69.

It is our business, then, to describe and explain these elementary processes, and to show that, when grouped and arranged in certain uniform ways, they give rise to the different complex processes that constitute human consciousnesses.

We shall have occasion, later on, to say something about various other processes that have been put forward as elementary. Many psychologists, for instance, accept an additional class of relational elements. A quotation from Herbert Spencer will show what is meant. "The proximate components of mind," he writes, "are of two broadly-contrasted kinds — Feelings and the Relations between feelings. [The word 'feelings' here may be taken

to include our sensations, images and affections.] Under an ultimate analysis, what we call a relation proves to be itself a feeling — the momentary feeling accompanying the transition from one conspicuous feeling to an adjacent conspicuous feeling. Notwithstanding its extreme brevity, its qualitative character is appreciable." [1] These relational processes we discuss in Pt. II. Again, some psychologists have postulated a conative element, or elementary process of will; others have set thoughts, as elementary processes, alongside of sensations and images. These, too, we discuss in Pt. II. The great majority of such pretenders may, however, be passed over in silence. They die and are dissected in the pages of psychological magazines, and do not live long enough to be mentioned in text-books.

§ 11. **Elements and Attributes.** — We have taken it for granted that the mental elements may be arranged in groups or classes. It may be objected that, since they are elements, — since they resist analysis, and cannot be reduced to anything simpler than themselves, — we can have no means of grouping them. How is it possible to find degrees of likeness and degrees of difference between absolutely simple things?

The psychologist arranges the mental elements precisely as the chemist classifies his elementary substances. The chemical elements are divided, for instance, into metals and non-metals. The metals have a high power of reflecting light; they are opaque; they are good conductors of heat and electricity; they have high specific gravities. So they are set off, as a group, from the non-metals. These latter, again, include both gaseous and solid elements. That is to say, the chemical elements possess certain prop-

[1] *Principles of Psychology*, 1881, vol. I., pt. ii., ch. ii., § 65. The quotation has been somewhat simplified.

erties or attributes, by means of which they may be distinguished and arranged.

It is just the same with the mental elements. These are simple, it is true, in the sense that they are mental experience reduced to its lowest terms; but they are still real processes, still actual items of mental experience. Hence, like the chemical elements, they show various aspects or attributes, — present different sides, so to speak, — each of which may be examined separately by the psychologist. It is by reference to these attributes that introspection is able to classify them under different headings. —

There is no more agreement in psychology about the attributes of the mental elements than there is about the elements themselves. It is, indeed, probably true to say that there is not so much; the lists given in the different text-books seldom correspond in all details.

Various reasons may be given for this divergence of opinion. It is often said, for example, that the psychologist must remain in doubt as regards the attributes of a mental element because he can never actually isolate the element itself, in order to bring it under separate observation. The human mind is so complex, and the avenues of approach to the human nervous system are so numerous, that he can never reduce consciousness to a single, simple process. Now in strictness this statement is, no doubt, entirely correct. At the same time, it is possible to arrange experimental conditions in such a way that, for all practical purposes, one process and one process only is presented for observation. If we rule out distracting influences, and concentrate the attention upon, say, a particular sensation, then this sensation stands out clear and distinct, and all the rest of consciousness becomes a vague blur of indifferent

processes. Practically, therefore, the psychologist can isolate a mental element, and can, as was said above, examine separately its various aspects or attributes. The reason for difference of opinion in regard to these attributes must be sought elsewhere.

The chief reason lies in the difficulty of deciding what is original in the sensation, inherent in it, constitutive of it, and what is mere accretion. The human nervous system, we must remember, has an immensely long history, is the outcome of long ages of development. The result is that it is full of short cuts; it is shot through and through with paths of direct connection. When, therefore, we think that we have a bare sensation before us, it is quite possible that we are, in reality, observing a complex process. What appears to be an aspect or attribute of the sensation may, in reality, be a separate process, so habitually and inseparably connected with the sensation in the past as now to seem an integral part of it. Let us take an instance.

We hear two tones, from the deep bass and the high treble. The former sounds voluminous and massive; the latter sounds small and sharp. Are we to conclude, then, that volume is an original attribute of tones? that tonal sensations possess a kind of solidity, a vague extension in the three dimensions of space? Some psychologists accept this conclusion. Others believe, on the contrary, that the volume which attaches to tones is a distinct process, and that it belongs not to hearing but to sight. When we hear a deep tone, that is, we are reminded of things that look large and soft; and when we hear a high tone, we are reminded of things that look small and hard: there is nothing large or small, soft or hard, about the tones themselves. Here, then, is the difficulty, — in deciding what is inherent

in tonal sensation and what is merely accessory: there is no difficulty in isolating the tones for separate observation.

Another reason may be found in the fact that, the more closely a particular kind of element is studied, the more many-sided is it likely to appear. Hence the specialist in any department of psychology will sometimes claim for his elements a larger number of attributes than the student of general psychology can discover in them. We may again illustrate this difference of opinion by reference to tones. Most of us would be disposed to think that a sensation of tone is characterised, simply and sufficiently, by its pitch, its definite position — high or low — upon the tonal scale. But the special student tells us that what we take to be a simple attribute of pitch is, in point of fact, the unanalysed resultant of no less than three distinct attributes.

Agreement will come with time; persistent observation, refining the longer it is continued, will someday settle the questions that we are here discussing. Meanwhile, the important thing is that we keep our minds open, and observe as carefully and impartially as we can. And if there are many occasions when we must speak less positively than we could wish, there is, on the other hand, the comforting reflection that an unfinished science is a good deal more interesting than a science whose facts and laws are already cut and dried.

§ 12. **The Attributes of Sensation.** — A sensation, as the term is used in this book, may be defined as an elementary mental process which is constituted of at least four attributes, — quality, intensity, clearness and duration. There are sensations for which the list of attributes is longer; but

these four are essential. We will consider them briefly, in the order of mention.

Quality is, so to say, an individual attribute; it is the attribute which distinguishes every elementary process from every other. It is, accordingly, the attribute which gives a sensation its special and distinctive name: cold, blue, salt, $b^\flat$, — these are all names of sensation qualities. Intensity is the attribute to which we refer when we say that a given sensation is brighter or duller, louder or fainter, heavier or lighter, stronger or weaker, than another sensation. In making such comparisons, we think of the sensations as possessing the same quality: both are blue, both are $b^\flat$, both are pressure, both are cold or salt or asafoetida: but these two sensations, of the same quality, lie at two different points upon a finite scale of sensation degrees, which begins at a lower limiting value and rises to a maximum. The more intensive sensation is placed higher up, the less intensive lower down, upon the scale of intensities. Clearness, again, is the attribute which gives a sensation its particular place in a consciousness: the clearer sensation is dominant, independent, outstanding, the less clear sensation is subordinate, undistinguished in the background of consciousness. If, for instance, we are listening to tones in order to decide whether or not they all alike possess the attribute of volume, the sensations are clear; if we are absorbed in work of a different kind, and someone is experimenting with tones in the next room, we still have the tonal sensations, but they are obscure. Lastly, duration is, as its name implies, a temporal attribute; it is the attribute which makes the course of a sensation in time — its rise, poise and fall as process in consciousness — characteristically different from the course of another sensation.

All sensations, without exception, possess the attributes of quality, intensity, clearness and duration. The list may be lengthened in two ways: by the splitting up of an attribute which has hitherto been regarded as simple, and by the discovery of attributes altogether different from the essential four.

On the first point, we have already remarked that what appears to ordinary observation as a simple attribute of quality may turn out, on closer examination, to be the unanalysed resultant of two or three distinct attributes. This is the case with tones, and also, as we shall see presently, with colours. The second point is best illustrated by reference to sight and touch. Sensations of colour are spread out areally into length and breadth; they appear as spatial extents. And this attribute of extent is part of their very constitution. Reduce the colour to a pin point, and it still occupies space; think away the spatial attribute, and the sensation has disappeared with it. So with pressures: set the point of a stiff horse-hair lightly down upon the skin, and the sensation is extended, diffused over a mental area. Certain sensations, then, have this attribute of extent; others, as odours and tones, show no trace of it. We come back to these facts, in detail, when we discuss the various classes of sensations.

The longest list of attributes is possessed by colour sensations. What we ordinarily term the quality of colour is the resultant of three qualitative attributes: colour-tone or hue, light-tone or tint, and colour-depth or chroma. To these three must be added the intensive attributes of intensity proper, clearness, duration and extent.

It is to be noted that, in certain cases, the concurrence of two or more attributes gives rise to what we may call an

attribute of the second order. Thus, certain sensations have been credited with an attribute of insistence. They are self-assertive and aggressive; they monopolise consciousness, as a forward and pushing guest will monopolise conversation at a social gathering. We speak of the penetratingness of odours like camphor and naphthaline; of the urgency or importunity of certain pains or of the taste of bitter; of the obtrusiveness or glaringness of certain lights and colours and tones. This character of insistence is, however, not a new primary attribute of the sensations. It is the resultant of clearness conjoined with quality, or with intensity, or with quality and intensity together.

§ 13. **The Classification of Sensations.** — Introspection leaves no doubt that the sensations, regarded as qualitative processes, fall into a number of separate groups. All colour sensations, for instance, go together; all tonal sensations go together. Colours, again, are more akin to greys, and tones to noises, than are colours to tones. This kinship between certain sense qualities means, in general, that the sensations fall into continuous series, so that one can pass from quality to quality as if along a straight line, without leaving one's path or meeting with a gap or interruption. It is possible to travel in this way from bass to treble, through the middle tones of the scale, or from red to white, through a series of pinks: it is not possible to travel from a colour to a tone.

We may, then, classify sensations in terms of their introspective resemblances. We may also, with change of standpoint, classify them by reference to the body, since observation has shown that every group of sensations comes to us by way of a definite, specially developed bodily

organ. The sensations of a particular group will then be those whose parallel bodily processes, in spite of difference of detail, have the same general effect within the organism. We may accordingly speak of eye sensations, muscle sensations, etc. Such a list, if completed, would be perfectly accurate.

Finally, we may classify sensations by reference to the stimuli which arouse them. Sensations at large fall into two principal groups, according as their stimulus is external, originating outside the body, or internal, originating within the body. Light, the stimulus to vision, is an external stimulus; muscular contraction, the stimulus to muscular sensation, is an internal stimulus. We therefore distinguish between sensations of the special senses, which are stimulated from without, and organic sensations, whose stimulus consists in a changed state of the internal bodily organs from which they come.

Not all the sense qualities that are ordinarily grouped together fall into continuous series, like the series of colours and tones. We naturally think, for example, of the sensations of pressure and temperature as forming a group of qualities, although no transition is possible from one quality of the group to another. We naturally think, again, of the sensation of warmth as very closely related to the sensation of cold, although there are no qualities which join these two sensations, and although their sense organs are distinct. It might seem, then, that the sensations of pressure and temperature are bracketed together simply by reference to the skin as their common organ, and the sensations of warmth and cold simply by reference to their common stimulus. Nevertheless, there is a real introspective resemblance between them. Pressure is more like warmth and cold than it is like tone or colour; and we do not feel the jar, in passing from cold to warmth, that we should feel if the disappearing cold were followed by a low tone or a

faint odour. The kinship which introspection finds among these sensations is, in the last resort, a matter of conscious context: the sensations from part of consciousnesses of the same pattern, make the same sort of connections in consciousness, are more or less interchangeable in consciousness.

In making out a list of the various departments of sensation, we are at times compelled to speak in terms of sense-organ or of stimulus, for the simple reason that the sensations themselves have not received a name. There is, for instance, no name to designate the peculiar quality of the sensation aroused by contraction of striped muscle. Language has developed at the command, not of theoretical interest, but of practical convenience; and there has been no pressing reason for the naming of all the separate sensations. Even in the case of colours, we have terms like violet and orange, the names of flower and fruit, alongside of the much older terms blue, red, etc.; and to denote a particular tone we have to use such clumsy expressions as 'the *c* of the thrice accented octave.'

References for Further Reading

§§ 10, 11. E. B. Talbot, *The Doctrine of Conscious Elements*, *Philosophical Review*, iv., 1895, 154.

M. F. Washburn, *Some Examples of the Use of Psychological Analysis in System-Making*, *Philosophical Review*, xi., 1902, 445.

E. H. Hollands, *Wundt's Doctrine of Psychical Analysis and the Psychical Elements, and Some Recent Criticism: 1. The Criteria of Elements and Attributes*, *American Journal of Psychology*, xvi., 1905, 499.

O. Kuelpe, *Outlines of Psychology*, 1909, § 40 (elementary quality of will).

§ 12. M. W. Calkins, *Attributes of Sensation*, *Psychological Review*, vi., 1899, 506.

M. F. Washburn, *Notes on Duration as an Attribute of Sensations*, *ibid.*, x., 1903, 416.

M. Meyer, *On the Attributes of the Sensations*, *ibid.*, xi., 1904, 83.

E. B. Titchener, *Lectures on the Elementary Psychology of Feeling and Attention*, 1908, Lecture i.

It should be said that current works on psychology differ, not only as regards the nature and number of the elementary mental processes and their attributes, but also as regards the principles and aims of psychological analysis in general. The fact is not surprising, when we remember that the fundamental questions treated in the Introduction — the questions of subject-matter, method and problem of psychology — are still in debate. The reader may compare with the discussion of the preceding paragraphs G. F. Stout, *The Groundwork of Psychology*, [1903] ch. iii.; C. H. Judd, *Psychology: General Introduction*, 1907, ch. iv. He should, nevertheless, look for underlying agreements rather than for superficial differences. Judd's preface, for instance, opens with the sentence: "There is very general agreement as to the main topics which must be treated in a text-book on psychology."

THE QUALITY OF SENSATION: VISION

§ 14. **The Visual Qualities.** — It needs but a casual glance at our surroundings, indoors or out, to assure us that the world of vision comprises a very large number of sense qualities. Besides all the wealth of colour, there is the whole scale of light, from the most brilliant white to the deepest black. Both alike are qualitative systems: black, white and grey, red, yellow, green and blue, — one and all are qualities of sensation, individual and elementary mental processes. To a certain extent, the sensations of light and of colour are independent of each other: a landscape or a coloured painting may be translated, by photography, into an arrangement of blacks, whites and greys. They are also, however, closely related. We speak of certain colours, without hesitation, as being darker or lighter, that is, nearer black or nearer white, than other colours; and we meet with colours of all grades or degrees, from the full quality, the deep red or rich green, to the merest tinge which is but a step from grey.

If we look, first, at the sensations of light, we find that they form a single linear series, extending from white through the lighter, neutral and darker greys to black. Language has very few words to denote the qualities of this series. We speak of black, for instance, as if it were a single quality. But glance, in succession, at black cardboard, black cloth, black velvet, and the black of a comparatively lightless space, — say, the blackened interior of

a long pasteboard tube. You realise at once, not only that these four blacks are qualitatively different, but also that their differences are quite considerable, so that there must be several intermediate blacks between the successive terms of the series. The same thing holds of white. Lay upon the window-sill a sheet of white paper, and on this place a cover-glass, silvered on the under side, in such a position that the glass reflects a patch of uniformly bright sky. The reflected light is astonishingly white, and the white of the paper seems, by comparison, greyish. There are in all, if we count up the distinguishable whites, greys and blacks, between six and seven hundred qualities of light sensation.

The system of colour sensations is less simple; the colour qualities cannot be arranged upon a single straight line. Let us take, as the arrangement of colours with which we are most familiar, a chart or a projection of the solar spectrum, and let us work through it, from the left or long-wave to the right or short-wave end. On the extreme left we have the quality of red. As we travel to the right, the red takes on more and more of a yellowish tinge, until it passes through orange to a pure yellow. Here, then, we have a linear series of qualities, precisely similar to the series of light sensations. Now, at yellow, we change our direction. The yellow gradually becomes tinged with a new quality, that of green; it passes through yellow-green to a pure green. Here is a second line of qualities. Again we change our direction; the green becomes more and more bluish, until it passes through blue-green to a pure blue. Here is a third line of qualities. Once more we change our direction. This time, however, the tinge that our initial quality takes on is not new; the blue becomes

increasingly reddish, as we travel to the right-hand end of the spectrum. Here is a fourth line of qualities, but a line which in the spectral series is left incomplete at violet. If we continue it, by adding the purples and carmines, we are finally brought back to our starting-point, — the red of the extreme left. We notice, however, that this red is not, in reality, the starting-point of a psychological colour-line; it is not a pure red, but an orange-red; the red that stands at the beginning of the red-yellow line lies outside the spectrum, toward the carmines.

All the colours that can be distinguished upon these four lines are ultimate qualities of visual sensation. We speak, it is true, of pure red and of orange-red; but these terms merely indicate the position of the qualities upon a colour-line: pure red comes at the beginning, orange-red towards the middle of the line. No orange-red can be analysed, by introspection, into a red and an orange. The lines themselves, and with them the system of colour qualities, are most simply arranged in the form of a square, with *R*, *Y*, *G* and *B* at the four corners.

So far, then, we have a single straight line to represent the sensations of light, and four straight lines, forming the closed figure of a square, to represent the sensations of colour. But so far, also, we have dealt with sensations of colour only under one aspect, — that of colour-tone or hue. Colours, as was said above, differ further from one another as darker and lighter. Thus, in the spectrum, yellow is undoubtedly the lightest, and violet the darkest colour. Here, then, is a second attribute of colour, the attribute of light-tone or tint, in virtue of which a sensation of colour may be matched or equated with a sensation of light. Let us assume that all the hues upon the lines of our colour-

square are of the same tint, and that this tint is that of a grey situated midway between white and black. Then, if the line of light sensations is erected as a vertical, the four colour-lines will lie about it in the horizontal plane, and at the level of this middle grey. All the lighter reds, or pinks, will stand in order above the point *R*, opposite the particular light greys to which their tint corresponds; all the darker reds will stand in order below *R*, opposite the dark greys to which their tint corresponds; and so with the lighter and darker *Y*, *G* and *B*. The vertical line, which represents the whites, greys and blacks, is thus surrounded by a square tube, whose walls are made up of all the hues in every possible variety of tint.

Suppose, now, that a line is drawn from some point on the wall of the tube to the corresponding point upon the vertical line: say, from the point *R* to the middle grey. The sensations that lie upon this new line form a series of the same hue and the same tint; but they differ in respect of a third attribute, that of colour-depth, or degree of saturation, or chroma. The red at *R*, which is farthest out from the corresponding grey, is a rich, full, deep red; it contains all the red that a visual sensation can contain, just as a saturated solution in chemistry contains all of the dissolved substance that it can contain; it shows the attribute of chroma at a maximum. As we proceed inwards, towards grey, the reds become less saturated, more washed-out; their chroma decreases and finally, when the grey is reached, entirely disappears.

As these chromatic lines may be drawn from any point upon the square shell to the corresponding point upon the vertical, our representation of visual sensations becomes a solid figure, a square prism. In actual observation, how-

ever, the lines are not all of the same length; they are longest for hues of a middle tint, shortest for hues of very dark and very light tints. There are, obviously, but few intermediate steps between a very dark blue and the corresponding greyish black, or between a very light yellow and the corresponding greyish white. The square prism thus becomes a double pyramid. At the two poles stand the extremes of white and black; upon the vertical axis, between the poles, are arranged the remaining sensations of light. Round the base of the figure lie all hues of a middle tint and of maximal chroma. Between base and poles lie the same hues in all their further variety of tint; all are still of maximal chroma, though the chromatic maximum decreases steadily, above and below. If we cut into the pyramid, from any point on the outside to a corresponding point upon the axis, we lay bare a series of sensations of the same hue and tint, but of varying chroma.

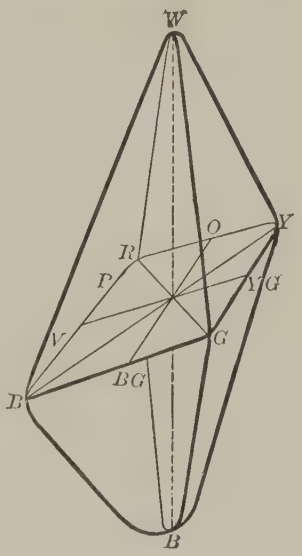

FIG. 2. The Colour Pyramid.

The double pyramid, then, as drawn in Fig. 2, embodies the two systems of visual sensation, sensations of light and sensations of colour, and shows these systems both in their mutual independence and in their mutual relations. There are at least a hundred and fifty distinguishable hues round the base. In counting up the whole number of visual sensations we must, however, take account also of

differences in tint and in chroma. These are ultimate differences: a pink is no more analysable by introspection into a red and a white than an orange-red is analysable into a red and an orange. All in all, the full tale of the visual elements cannot fall far short of thirty-five thousand.

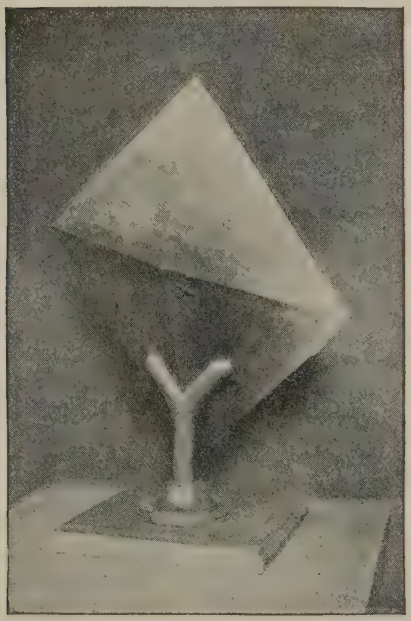

FIG. 3. Demonstrational Colour Pyramid. — *American Journal of Psychology*, XX., 1909, 15.

§ 15. **Visual Stimulus and Visual Sensation.** — The trains of ether waves which constitute light, in the physical sense, differ in three ways: in wave-length, in wave-amplitude or energy, and in wave-form or composition. In general, these three aspects of the ether waves correspond to the three attributes of colour sensation, — hue, tint and chroma. At the red end of the spectrum, the light-waves have a length, roughly, of 700 $\mu\mu$; at the violet end a length, roughly, of 400 $\mu\mu$; and the intervening hues are correlated with intermediate wave-lengths. If we increase or decrease the energy of these waves, within certain limits, the colours as a whole become lighter or darker, — there is a change of tint; but the distribution of hues, and the relative degrees of tint and chroma, remain unchanged. Lastly, the fact that the spectral hues possess a high

chroma, while the colours that we see in nature and art are less saturated, is due to the relative simplicity of wave-form in the one case and its relative complexity in the other. These are, however, only general correspondences. In detail, the relation between visual stimulus and visual sensation is very far from simple.

There is, indeed, one case — the case of the sensation black — in which there seems, at first thought, to be no relation at all. It is often said, paradoxically, that the stimulus to black is the absence of physical light. If this were true, black would stand apart from all the other visual qualities. But, on the one hand, what we see in the absence of light is not black. 'In the night all cats are grey'; and the absence of light means, in point of fact, that our surroundings appear in a neutral grey. On the other hand, we can see black only in a good light; so that the sensation of black, like the after-images and contrast-sensations of which we speak in § 18, is indirectly, although not directly, dependent upon the presence of physical light. We discuss the question of its origin in § 22.

Black is, of course, a positive sensation; as it is not due to the absence of light, so it does not represent the absence of visual sensation. To suppose that the blind live in darkness is altogether wrong, because it is to suppose that they are able to see. Blind persons see things, as Helmholtz puts it,[1] in the same way in which we ourselves see what is behind our backs: that is to say, they do not see them at all.

§ 16. **The Dependence of Visual Sensation upon Wave-length and Energy of Light.** — In general, as we have

[1] H. L. F. von Helmholtz, *Handbuch der physiologischen Optik*, 1896, 324.

said, change in the wave-length of physical light means change in the hue of colour sensation. This statement must now be qualified in three ways.

First, we find by reference to the spectrum that the correspondence of wave-length and hue is not uniform throughout the colour series. At the two ends, in *R* and *V*, we may travel for a considerable distance without noticing any marked change of hue. If, on the other hand, we look at the regions on either side of *Y*, or at the *BG* region, we see at once that a very large number of hues is there packed into a very small space. Secondly, we find that difference of wave-length brings with it a difference of chroma. The most saturated colours of the spectrum are *R* and *B*; the least saturated are *Y* and *BG*. Chroma, therefore, depends upon wave-length as well as upon wave-form. Thirdly, we find that change of wave-length brings with it a change of tint. We have already remarked that *Y* is the lightest and *V* the darkest colour of the spectrum. Now the energy of the light-waves decreases continuously from the long-wave to the short-wave end;[1] so that, if tint depended solely on energy or wave-amplitude, *R* and not *Y* should be the lightest colour, and *B*, as compared with *R*, should be much darker than is actually the case.

In the same way, change in the energy of physical light may change, not only the tint, but also the hue and the chroma of colour sensations. If the energy of the light-waves which form the spectrum is greatly increased, the

[1] This statement holds of the dispersion spectrum of an artificial light, such as is usually observed in psychological laboratories. In the diffraction spectrum of sunlight — what physicists term the 'normal' spectrum — the maximum of energy is in the blue.

hues are reduced to two, *Y* and *B*, both of light tint and low chroma. The *R*, *O* and *YG* of the original series become lighter and yellower; the *BG* and *V* become lighter and bluer; *G* becomes simply lighter, and finally passes into a light grey. If the energy is greatly decreased, the hues are reduced to three, *R*, *G* and *BV*, all of dark tint and low chroma. At the same time there is a marked change in the relative distribution of tint throughout the spectrum: all the colours are darker, but the position of the relatively lightest tint moves from *Y* to *G*, — so that the long-wave end is darkened, and the short-wave end lightened, in comparison with the ordinary spectrum. This shift of tint with decrease of energy is called, after the Austrian physiologist who first observed it, the Purkinje phenomenon.[1]

The Purkinje phenomenon appears most clearly when the energy of the spectrum has been so far diminished that the colours fade out altogether, and only a series of sensations of light is left. It appears, in any case, only if the energy of light is decreased over the whole field of vision; it is not enough to reduce the energy of the spectrum alone. You may get an idea of it by laying pieces of red and blue paper side by side, and observing them first in ordinary diffuse daylight and then through a pin-hole in a card. Or if you watch the reds and blues of a carpet, as twilight comes on, you will notice that the reds quickly become dark grey or black, while the blues change into a silvery blue-grey. This aspect of the phenomenon, in which it depends upon the general illumination of our surroundings, is dealt with in §§ 19, 22.

§ 17. **The Dependence of Visual Sensation upon Composition of Light.** — In tracing out the dependence of visual sensation upon the form or composition of light-waves, we

[1] J. Purkinje, *Beobachtungen und Versuche zur Physiologie der Sinne*, ii., 1825, 109.

may most conveniently employ the colour-mixer, with compound discs of the sort mentioned in § 6. Everyone knows that a glowing match, whirled round in the air, is seen as a fiery circle: the effect produced upon the eye by the moving stimulus persists for a time, in what is termed the positive after-image, until the stimulus comes back again to the same point. This is the principle which underlies the use of the rotating discs. It is, further, a law of physiological optics that if such particoloured discs are rotated at a rate of speed sufficient to prevent flicker, the resulting impression upon the eye is the same as it would be if the physical light, reflected from the several sectors, were spread uniformly, layer on layer, over the whole disc-surface.[1] From this point of view, then, the use of the discs is as safe as it is convenient. Whether we may argue from the results obtained with the discs to the results obtainable with other forms of stimulus, — whether, more especially, we may argue from the disc-colours to the pure lights of the spectrum, — is a question which experiment must decide. We return to it presently.

The facts to be considered in this section may be grouped under three laws, which are known as the laws of colour mixture. The first law states (1) that for every colour there may be found another, antagonistic or complementary colour, which if mixed with it in the right proportions produces a sensation of light, and if mixed in any other proportions a colour sensation, of low degree of chroma and of the hue of the stronger component. An-

[1] This law, called Talbot's law, was first propounded in 1834 by the physicist W. H. F. Talbot, one of the inventors of photography (*The London and Edinburgh Philosophical Magazine and Journal of Science*, series 3, v., 328 ff.).

tagonistic colours, in this sense, are carmine and bluish green, red and verdigris, orange and greenish blue, yellow and blue, yellowish green and violet, green and purple. The second law states (2) that the mixture of any two colours which are not antagonistic produces a colour sensation of intermediate hue; this hue varies with the relative amounts of the two component colours, and the chroma varies with their nearness or remoteness in the colour series. Thus, a mixture of *R* and *B* will give violet, purple or carmine, according to the amounts taken; and the

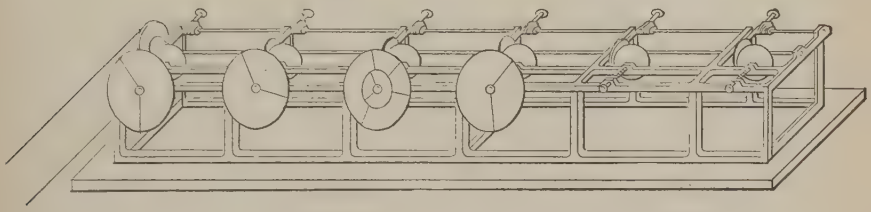

FIG. 4. Demonstrational Colour Mixer, for six sets of discs.

mixture of *R* and *Y* will give an *O* of relatively low, that of *RO* and *OY* an *O* of relatively high chroma.

These two laws are, evidently, laws of the same order; they sum up observations of the same general kind. The third law takes us a step farther and shows the effect of mixing, not single colours, but colour mixtures. It is sometimes termed Newton's law of colour mixture, since it is implicit in his theory of the composition of light.[1] We may formulate it as follows: (3) if two colour mixtures arouse the same sensation of light or colour, then a mixture of these mixtures will also arouse that sensation. If, for instance, the grey produced by a mixture of car-

[1] I. Newton, *Opticks: or, A Treatise of the Reflections, Refractions, Inflections and Colours of Light*, [1704] bk. i., pt. ii., props. 4–6.

mine and bluish green is the same as that produced by a mixture of red and verdigris, then this grey will also result from the mixture, in the original proportions, of all four colours. — This third law enables us to answer in the affirmative the question, raised above, whether it is legitimate to argue from our disc-colours to other forms of visual stimulus, and especially to the pure lights of the spectrum.

The answer is reached by way of the corollary that any unsaturated colour may be produced by mixture of a saturated colour with grey. The disc-colours are relatively unsaturated colours; they are compounded, physically, of a number of different colours, with some one colour (or some small group of neighbouring colours) in the ascendant. Now the first law declares that the mixture of complementaries produces grey. By the third law, which asserts that all colour mixtures have a constant mixing value, any grey whatsoever may be considered as the result of mixture, in the right proportions, of some pair x, y of complementary colours. If y is present in excess, then by the first law we obtain a colour sensation of low chroma and of the hue of y itself. Hence all that we have to do, in order to produce a particular unsaturated colour, is to search among the saturated colours for the fitting y, and, having found it, to add a certain amount of grey. This means, however, that our disc-colours may be regarded as spectral colours mixed with various amounts of white light, and therefore that our demonstration of the three laws holds for the spectrum as well as for coloured papers.

There are other important corollaries to these laws. Thus, it follows from the first and second, taken together, that the mixture of three colours, every pair of which embraces the complementary of the third, will give colour sensations of every possible hue, and of all possible degrees of chroma from a certain maximum to zero. Take, for example, R, G and V. The mixture of R and G will, by the second law, give any hue from the O, Y and YG regions; the mixture of G and V will give BG and B; the mix-

ture of *V* and *R* will give *P* and *C*. Further, the complementary of *V* lies between *R* and *G*; that of *R* between *G* and *V*; and that of *G* between *V* and *R*. Hence, by a fittingly proportioned mixture of these three colours, it is possible to obtain a colour sensation of any required hue, and of any degree of chroma that is lower than that of the components. Similar triads of colours are *R*, *Y*, *GB*; *O*, *G*, *V*; *P*, *YG*, *BG*; etc. — This is a useful corollary to us, since it is seldom that the disc-colours are exactly complementary. Hence, to demonstrate the complementarism of *C* and *BG*, we take three coloured papers, *C*, *B* and *G*, and vary the proportions of the sectors until we find a *BG* that is antagonistic to the given *C*; and so on with other complementary pairs.

It follows, again, from the third law, as we have formulated it above, that colour-equations are independent of the energy of the physical stimulus. Suppose, for instance, that we have matched a grey derived from *C* and *BG* to a grey derived from *B* and *Y*. Now assume that the energy of these greys is doubled or tripled. This is the same thing as assuming that we have made the match two or three times over, and then added the greys together, mixed each grey once or twice with itself. The resulting double or triple greys ought, by the law, to match as well as the original, single greys. Here, however, we may come into conflict with the Purkinje phenomenon. If the equation is first made for a low degree of light-energy, and this energy is then considerably increased, the *B-Y* grey will evidently appear lighter than the *C-BG* grey. If, contrariwise, the equation is first made for a moderately high degree of light-energy, and the energy is then greatly diminished, the *C-BG* grey must appear lighter than the *B-Y* grey. And for certain shifts of energy the change of tint will be accompanied by a change of hue. Neither this corollary, therefore, nor the third law itself, in so far as it involves the corollary, can be regarded as valid under all conditions.

§ 18. **The Dependence of Visual Sensation upon the Time and Space Relations of Stimulus.** — The quality of visual sensation is dependent not only upon the wave-length, wave-

amplitude and wave-form of light, but also upon the time during which the waves affect the eye and upon their distribution in space. Under the former heading, we have to consider the facts of adaptation and of negative after-images; under the latter, the facts of light and colour contrast. —

When the lamps are first lighted in the evening, we clearly realise that the illumination is not white but reddish-yellow. As time goes on, however, this colour disappears, and the objects about us look as they would look in a really white light. In ordinary language, we have grown accustomed to the artificial light; in technical terms, adaptation has set in. The law of adaptation is that all sensations of colour tend towards neutrality, and all sensations of light towards a middle grey. Adaptation may be either general, extending over the whole field of vision, or local, extending over some part of the field to which our gaze is constantly directed.

The course of general adaptation to colour may be followed by help of an optician's trial frame and a set of coloured glasses. If, for instance, you wear a pair of yellow glasses even for five minutes, you will find that adaptation has gone surprisingly far. Adaptation to dark and light is never so complete as adaptation to colour: the grey that you see after waking from sleep in a dark room and the grey that you see out of doors on a dull winter's day when the ground is covered with snow are distinctly different, the one lying on the black and the other on the white side of the middle grey. Nevertheless, there is a definite approach to this grey; after you have worn 'black' glasses for a few hours, it is difficult to believe that the world looks darker than it did before you put them on.

Local adaptation may be demonstrated by the apparatus shown in Fig. 5. Gaze steadily, say for 1 min., at the button which lies at the centre of the line of junction of black and white. You soon

see grey films or clouds, which appear first along this line and gradually spread, to right and left, over the whole surface. On the black, the cloud is dark and slowly lightens; on the white, it is light and slowly darkens. Both clouds are strongest at the centre, weaker towards the periphery. (The lines of brilliant white and intense black, that flash out from time to time, are irrelevant to the present observation; they are due to involuntary slips of fixation.) — The black and the white are, evidently, tending both alike towards a middle grey. Indeed, if the gaze is maintained for a sufficient length of time, their difference disappears, and the entire surface is seen as a uniform grey. Similar tests may be made with colours.

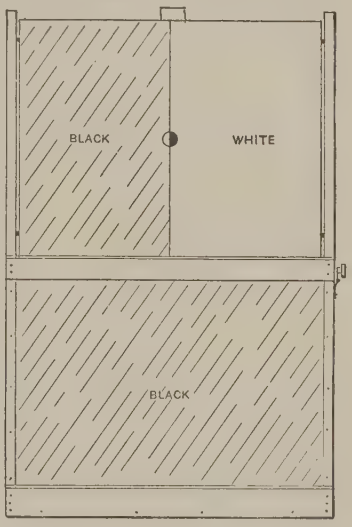

FIG. 5. Adaptation Frame.

It is plain that this law of adaptation may be brought into relation with the laws of colour mixture. To say that, under adaptation, all sensations of colour tend towards neutrality is equivalent to saying that, as time goes on, every colour in the field of vision is mixed with an increasing amount of its antagonistic colour. To say that, under adaptation, all sensations of light tend towards a middle grey is equivalent to saying that, as time goes on, the blacks in the field of vision are mixed with increasing amounts of white, and the whites with increasing amounts of black. Adaptation to colour suggests the first, adaptation to light suggests the second law of colour mixture.

Let us turn, now, to the after-effects of adaptation.

When you come out into the daylight from a matinée performance, everything looks curiously bluish; when you pass from daylight into a darkened room, everything is oppressively black. Very soon, of course, the blue wears off and the black clears up; a novel adaptation is in progress. But the immediate after-effect of general adaptation is always this contrary trend of vision: if you were yellow-adapted, you are now blue-sighted; if green-adapted, now purple-sighted; if dark-adapted, now light-sighted.

The same thing holds of local adaptation. If, by steady fixation, you have brought a patch of colour to disappearance, and the colour stimulus is then removed, you see in place of it a patch of the antagonistic colour, a negative after-image. A yellow stimulus gives a blue after-image; a green stimulus, a purple after-image; a black stimulus, a white after-image.

The after-effect of general adaptation may be demonstrated with the coloured spectacles. When, for instance, the yellow glasses are taken off, all the blues in the field of vision look extremely saturated, all the yellows look whitish, and the other colours appear as if mixed with blue.

To demonstrate the negative after-image, we may continue the observation made with the adaptation screen (Fig. 5). If, at the end of the 1 min., the half-black and half-white card is allowed to fall, and there is shown in its place a background of uniform grey, the observers will see an intense black where they previously saw white, and a brilliant white where they previously saw black. (The black and white lines, spoken of above, owe their depth and brilliancy to the fact that, as fixation slips, the white edge falls upon a black-adapted part of the retina, and conversely: the white is thus seen with a white-sighted eye, and the black with a black-sighted eye.) After-images of colour may be demon-

strated by the apparatus shown in Fig. 6. A disc of coloured glass is fixated, say, for 30 sec. Then a grey screen is dropped between glass and lamp, and the after-image develops, in the antagonistic colour, upon this screen.

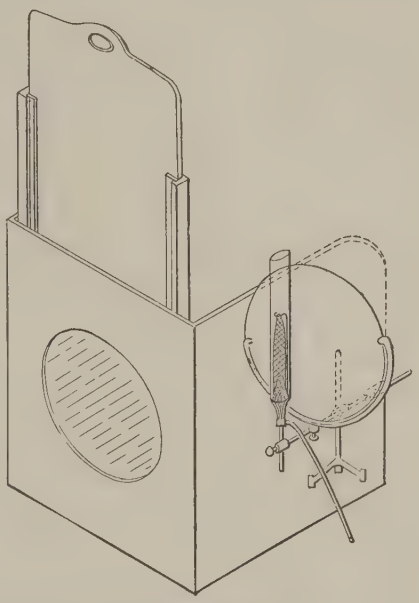

FIG. 6. Wundt's Apparatus for the Observation of Negative After-Images.

It is a little puzzling that, in all these phenomena of adaptation, black and white should behave, in the sphere of sensations of light, as complementary colours behave in the sphere of sensations of colour. We saw in § 14 that the series of light sensations, white-grey-black, resembles the *R-Y*, *Y-G*, *G-B* and *B-R* series of colour sensations; and we have just said that the course of adaptation to light suggests, in consequence, the second law of colour mixture. But *Y*-adaptation does not leave us *G*-sighted, nor does *R*-adaptation leave us *Y*-sighted or *B*-sighted: why, then, should white-adaptation leave us black-sighted, and conversely? We seek to answer this question, and so to bring all the facts of adaptation under a single principle, in § 22. In the meantime, we notice that, in the domain of contrast, black and white again appear in the same antagonistic or complementary relation. —

Contrast is the name given to the effects produced for sensation by the distribution of visual stimuli in space. Every patch of light and colour in the field of vision affects and is affected by all the rest in certain definite ways. The principal laws of contrast — that is, of this reciprocal induction of lights and colours — are as follows. (1) The contrast-effect is always in the direction of greatest opposition; a yellow makes its surroundings bluish, a black makes its surroundings light. (2) The nearer to-

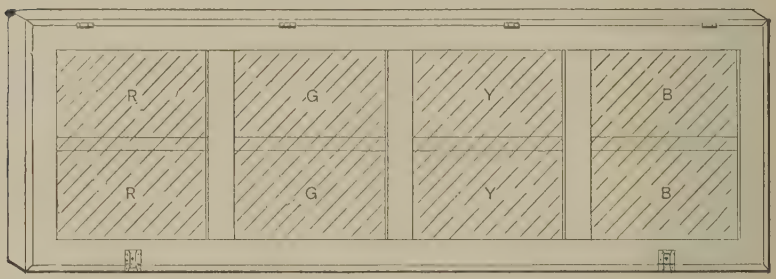

FIG. 7. Contrast Frame.

gether the contrasting surfaces, the greater is the contrast-effect. We may therefore distinguish between marginal contrast, in which the effect is maximal, and surface contrast, in which it is less marked. (3) The contrast-effect is enhanced by the elimination of contours or boundary-lines. — There are two further laws of colour contrast: (4) that the effect is greatest when there is no simultaneous-light contrast; and (5) that the effect increases with increase of the saturation of the inducing colour.

A general idea of the phenomena of contrast may be gained from the contrast frame, shown in Fig. 7. The frame contains four sheets of coloured paper, — *R*, *G*, *Y* and *B*. Across the centre of these sheets is laid a horizontal strip of neutral grey paper. Each panel is faced with white tissue, which serves to

bring colour and grey into the same plane, and also to obscure the outline of the grey strip. Under these conditions the grey appears in four different colours, which are complementary to the colours of the sheets, and whose tint varies inversely with the tint of the coloured background. The strip is so narrow that marginal contrast is secured over its whole width.

Very beautiful contrast-effects may be obtained with coloured shadows. Fig. 8 shows two window-slits cut in the wall of a dark room, the one filled with a blue, the other with an ordinary ground glass. A black rod, standing on a table, casts two shadows upon

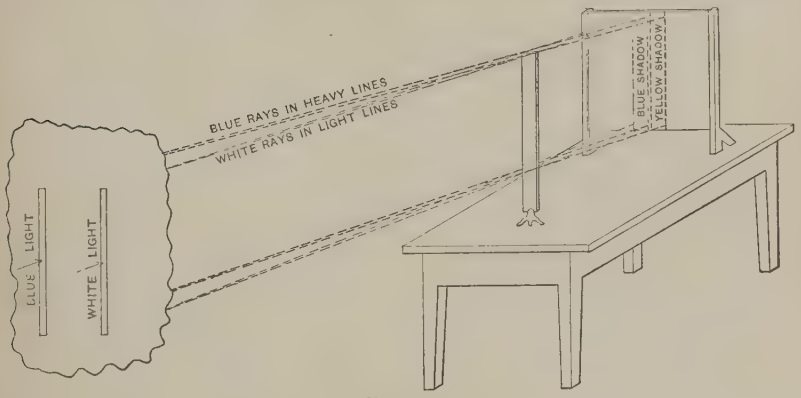

Fig. 8.

a white screen. The farther shadow, due to the white light from the nearer slit, is illuminated by the blue light, and therefore appears blue. The nearer shadow, due to the blue light from the farther slit, is illuminated by the white light, and should therefore, in terms of its physical stimulus, appear light grey. In reality, it appears, by contrast, in the yellow complementary to the blue of its neighbour. — The rod should be moved to and fro, until the shadows are exactly juxtaposed; their lack of definite contour, their narrowness, and their identity of plane, all serve to enhance the contrast-effect. It is, indeed, easily possible, by varying the widths of the window-slits, to give the yellow a higher degree of chroma than is possessed by the blue shadow, so that a naive observer would unhesitatingly declare the blue to be the contrast,

and the yellow the 'real' colour. The bluish tinge of the background shows, of course, that the yellow colour is due to contrast. — Other coloured glasses may be substituted for the blue, with similar results.

It is clear, from all these facts, that the lights and colours of the field of vision, at any given moment, are not exclusively determined by the physical stimuli, the reflected light-waves, which affect the eye. What we see depends, in part, upon contrast; in part, also, upon the preceding adaptation of the eye, general and local. It is clear, further, that contrast and adaptation are in one sense opposed, but in another sense mutually supplementary principles. Contrast is present, throughout the field of vision, as soon as we open our eyes; adaptation requires time. Contrast is a differentiating, adaptation a levelling principle. Hence contrast helps us to discriminate all the separate objects by which we are surrounded, while adaptation prevents our being fatigued or disturbed by their variety after this discrimination has taken place.

§ 19. **Daylight and Twilight Vision.** — The human eye is a single sense-organ, and all its sensations are of one general kind. But it is also an extremely elaborate organ, the final product of a long course of development and differentiation. We must, therefore, consider visual sensation not only in its dependence upon external stimulus, but also in its dependence upon differences of structure and function within the eye. We shall not, in this way, discover any new sense-qualities; but we shall bring the sensations of light and colour into a novel perspective, and shall thus find uniformities which will help us, later on, towards their physiological explanation.

The facts of which we have to take account are, first, those of daylight and twilight vision; and, secondly, those of direct and indirect vision and of colour blindness. The former have already been touched upon, incidentally, in references to the Purkinje phenomenon.

It is, indeed, a curious thing that our sight undergoes a radical transformation as we pass from the light to the dark and back again. So long as the energy of the light-waves that strike the eye is maintained above a certain limit, we have daylight vision. We see the spectrum as a band of colours, with yellow as the lightest tint; we have all degrees of light sensation, from white to black; in a word, our vision is the vision that is summed up in the colour pyramid. When, on the other hand, the energy of the light-waves falls below this limit, we have twilight vision: the spectrum is seen as a band of greys, the lightest of which lies in the region occupied in daylight by the green, and sensations of colour are altogether lacking. Under certain conditions, the two modes of vision overlap. Twilight vision is greatly enhanced by adaptation of the eye to dark; so that, if there is sufficient light for us to distinguish colours, while at the same time the eye is partially dark-adapted, we see the Purkinje phenomenon superposed upon daylight vision. On the other hand, this overlapping is not possible over the whole extent of the retina. At the very centre of the eye, there is no twilight vision, and the Purkinje phenomenon does not appear. So far, then, the two modes of vision are locally separated: while the eye in general is composed, so to say, of two eyes, a nyctalopic and an hemeralopic, a small area in the middle of the retina is permanently hemeralopic.

We said in § 16 that the Purkinje phenomenon might be observed by looking at red and blue papers through a pinhole in a card. It may also be observed by looking at the colours through nearly closed eyelids, or by taking them from a light into a dark room. In all three cases, since the colours are still visible, there is a mixture of daylight and twilight vision; that is to say, the phenomenon does not appear at once, but only after a little while, when dark-adaptation has gone a certain distance. A similar mixture of the two types of vision occurs as you watch the reds and blues of the carpet in a deepening twilight. If, on the other hand, you go straight from bright daylight into a perfectly dark room, in which is exposed a spectrum of such low energy that no colour can be seen, then, as soon as you are able to observe at all, you observe that this spectrum shows the Purkinje phenomenon. Twilight vision is primarily dependent, not upon dark-adaptation, but upon the reduction of the energy of light. What dark-adaptation does is to make the greys of twilight vision much clearer and stronger than they are without it.

The absence of the Purkinje phenomenon at the centre of the retina can be demonstrated only by aid of refined physical instruments. It is, however, easy to convince oneself that this central area, which in daylight is preferred for all the most delicate uses of vision, is not stimulable by light-waves below a certain limit of energy. Look directly, on some dark night, at a faint star or a distant lamp that is just visible as the eye travels over the field of vision, and the point of light disappears. Shift your gaze ever so little from this direct fixation, and it flashes out again.

We can now understand the exceptions to the third law of colour mixture, mentioned in § 17. Colour equations made in daylight vision will hold in daylight vision: they cease to hold when we exchange this for twilight vision, or when in consequence of dark-adaptation twilight encroaches upon daylight vision.

§ 20. **Indirect Vision and Colour Blindness.** — Under ordinary circumstances, we pay but little attention to the outlying parts of the field of vision. What we want to

see, we look at, and so bring upon the centre of the retina; and we take it for granted that the visible objects which lie far out in the field, round about this region of direct regard, retain the colours which they show when we turn the eye upon them. Nevertheless, the colour vision of the peripheral retina is very different from that of the centre.

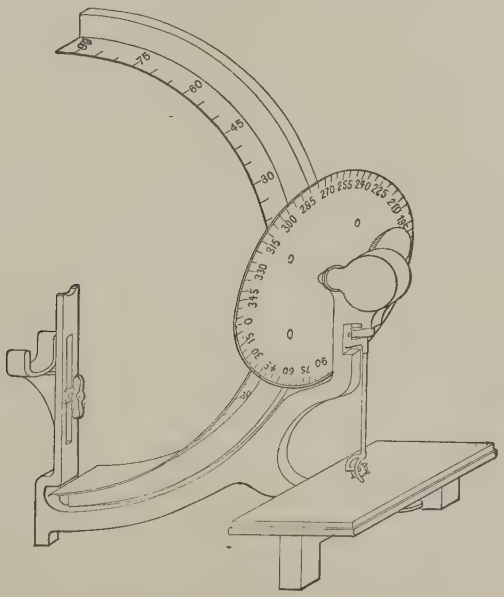

FIG. 9. Perimeter for Mapping the Retinal Zones.

Suppose that the left eye is shaded, and that the right gazes steadily at some fixation-mark placed directly before it, or a little to the right. Suppose, further, that a small red object is moved into the field of vision from the nasal side, so that its image falls upon the temporal half of the right retina. The object first becomes visible as a patch of black; then it shows as *B* or *Y*; then, as it advances, it looks *P* or *O*; finally, as it approaches the fixation-point,

it appears in its true colour, as a carmine or vermilion. Other colours give like results; so that we are finally led to the conclusion that the retina consists of three distinct zones. The outermost zone is totally colour blind, and accordingly furnishes only sensations of light, whatever the stimulus may be. The intermediate zone is partially colour blind and furnishes, besides the sensations of light, only sensations of *B* and *Y*, in all tints and in all degrees of chroma. The middlemost or central area furnishes all the sense-qualities that are represented in the colour pyramid.

We have called the three zones distinct, and it is true that they may be distinguished in any experiment such as that just described. At the same time, as the *P* or *O* phase of the observation shows, they are not sharply separated, but pass gradually into one another. Hence a red object of large area will still be seen as *R* where a smaller object would appear as *P* or *O*, and will still be seen as coloured where a smaller object would look dark grey or black. Similarly, a stimulus of high energy and brief duration will retain its colour farther from the centre than a stimulus of low energy and longer duration. It is, therefore, impossible to map the retinal zones in any hard and fast way. They are regions of relatively, not absolutely different colour sensitivity. Indeed, if the energy of the stimuli were made exceedingly great, it is probable that they would be seen in their true colours over the whole extent of the retina. Under the usual conditions of stimulation, however, the zones are distinct.

A red stimulus, as it travels out from the centre, changes first to *P* or *O*, and then to *B* or *Y*, only because it is not a physiologically pure red. If we can find a red stimulus that has no *B* or *Y* effect, then the red will change to black or grey as soon as it leaves the middlemost zone. This red has, as a matter of fact, been determined; it is not a spectral red or vermilion, but a slightly purplish or carmine red. What holds of it holds also of

its complementary, a spectral hue of about 495 $\mu\mu$; this, too, passes directly into grey as it leaves the middlemost zone. If these two colours are equated as regards area, tint and chroma, they become colourless at the same distance from the centre of the retina, so that the zone of red-vision is coextensive with the zone of green-vision. The same thing is true of a *B* of about 470 $\mu\mu$ and a *Y* of about 575 $\mu\mu$: the zone of *B*-vision is coextensive with that of *Y*-vision. The retina thus appears as made up of an outermost *Bk-W* zone, an intermediate *Bk-W* + *B-Y*, and an innermost *Bk-W* + *B-Y* + *R-G* zone.

If a spectrum is thrown upon the *Bk-W* zone, it appears, of course, as a band of greys. It is noteworthy that, in light-adaptation, the lightest of these greys occupies the region of the yellow, so that the relative distribution of tint in the colourless spectrum is unchanged. —

Most of us use our eyes for a lifetime, without discovering these differences of zonal sensitivity. The reason is that, in indirect vision, it is very difficult to make out the form, size or contour of objects in the visual field. This sort of discrimination is, however, of great importance for the organism. Hence we habitually turn our eyes toward that which we wish to observe; attention goes with direct vision, and the phenomena of indirect vision are disregarded.

We must say, then, that the normal eye is normal only for purposes of direct vision, while in indirect vision it is partially or totally colour blind. There is also an abnormal colour blindness; certain persons show these defects of vision over the whole extent of the retina. Thus, some 3 per cent. of the male population are, from birth, partially colour blind; their eyes lack the middlemost or *R-G* zone. The physiologically pure red and the physiologically pure green, of about 495 $\mu\mu$, appear to them as grey; the left or long-wave end of the spectrum is yellow, and the right or short-wave end is blue. In other words, the spectrum

looks in direct vision as it normally looks in indirect vision with the *Y-B* zone, or as it normally looks in direct vision when the energy of the light-waves is very great (§ 16); and the whole visual world consists of blacks, whites and greys, together with blues and yellows in all possible variety of tint and chroma.

It follows from this that partially colour blind persons will confuse a pure red and a pure green, if tint and chroma are the same. They will also, under these conditions, confuse *O* and *YG*, *P* and *BG*, rose and blue, vermilion and brown. In everyday life they make very few mistakes, partly because they have learned the names of coloured objects from their normal-sighted acquaintances, partly because objects of the confusable colours usually differ in tint or chroma or both, as well as in hue, and in certain cases because difference of hue is connected with a difference of grain or texture.[1]

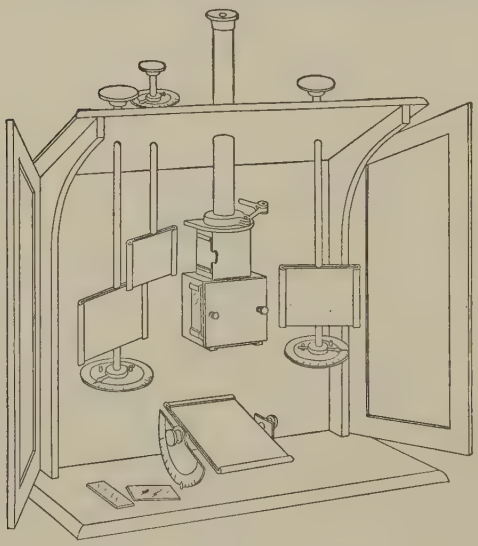

FIG. 10. Hering's Apparatus for the Investigation of Partial Colour Blindness.

[1] This, no doubt, explains the otherwise curious fact that only in comparatively recent times has partial colour blindness attracted any widespread attention. Scattered references to it go back to the seventeenth century; but it did not obtain general recognition from scientific men until 1798, when the chemist John Dalton published a paper on Extraordinary Facts relating to the Vision of Colours (*Edinburgh Journal of Science*, ix., 97). Dalton was himself partially colour blind, and for some time the defect was known as Dalton-

There are two types of partial colour blindness. In the first and commoner form, the distribution of tints in the spectrum is the same as in normal vision; the lightest grey lies in the region of yellow. In the second, the lightest grey has shifted towards the short-wave end, and lies in the region of yellow-green. This and certain other anomalies of congenital partial colour blindness still await explanation. — A partial colour blindness due to lack of the intermediate or *B-Y* zone is found only as a pathological condition of the eyes, not as a congenital defect.

A much more serious congenital defect of vision is that known as total colour blindness, in which the eye lacks both the *R-G* and the *B-Y* zones, and the world of colour appears in monotone as an arrangement of blacks, whites and greys. The defect is rare; only some fifty cases have been examined. The totally colour blind eye is nyctalopic; that is to say, its vision, in any state of adaptation, is twilight vision, and the spectrum as seen by it always shows the Purkinje phenomenon. Further, the small central area which, in the normal eye, is permanently hemeralopic is in the totally colour blind eye either wholly or almost wholly blind, so that direct fixation of an object in the field of vision is impossible, and the eye twitches and jerks in the effort after clear vision.

§ 21. **The Primary Colours.** — We have seen that, psychologically regarded, all colours are equally simple; it is impossible, for instance, by introspective analysis to split up orange into yellow and red. On the other hand, certain colours have exceptional positions in the colour pyramid, — those colours, namely, which lie at the four corners of

ism. Latterly the subject has been much discussed, on account of the danger arising from the confusion of red and green signal lights by engineers, pilots, etc.

the base, and which thus begin and end the four colour series. These colours, *R*, *Y*, *G*, *B*, are the psychological primaries.

For technical and artistic purposes, we must give this title to a different set of colours: *R*, *Y* and *B*. The painter who has these pigments upon his palette is able by their means, with the help of white, to reproduce the various colours of nature.

It is a matter of common experience that the mixture of *B* and *Y* paints will give a saturated green. The reason is that the blue pigment crystals reflect *B* and *G* light, the *Y* crystals, *Y* and *G* light. Thus the *B* and *Y* cancel each other, and only the *G* is left to be seen.

For the physicist, again, the primary colours are *R*, *G* and a certain *BV*. The mixture of these three spectral colours, in fitting proportions, will not only give colours of every possible hue, but will also give them at a higher degree of saturation than can be obtained from any other three spectral colours.

Lastly, for the physiologist, the primary colours are the four characteristic colours of the retinal zones: a purplish red, its complementary bluish green of about 495 $\mu\mu$, and the *Y* and *B* of the intermediate zone. The two latter colours are identical with the psychological primaries. Whether the physiologically pure *R* is identical with the psychological *R* is doubtful; but it is certain that the physiological *G* is not the psychological *G*: it is rather a distinctly bluish *G*.

Evidently, then, the term primary is misleading; what it means depends upon the context in which it is used. We may, perhaps, call the psychological *R*, *G*, *Y*, *B* the principal colours; the artist's *W*, *R*, *Y*, *B* the primary

colours; the physicist's R, G and BV the fundamental colours; and the physiological C, BG, Y and B the invariable colours.

§ 22. **Theories of Vision.** — The eye[1] is, in all essentials, a little photographic camera. The eyelids form a cap or shutter, closure of which prevents the access of light. Behind the shutter is an automatic diaphragm, the iris, which closes to a pin-hole or opens out, according to the degree of illumination. Behind the diaphragm is a lens, which may be adjusted for near or far objects. This adjustment is not made by changing the length of the eyeball, as it were by racking the lens back and forth; the soft substance of the lens is encased in an elastic sheath, which is suspended by radial fibres to muscles set vertically in the wall of the eyeball. When the eye is at rest, the anterior surface of the lens is relatively flat, and the organ is consequently adjusted for far vision; if we wish to focus upon a near object, the muscles contract, the pull on the radial fibres is thereby lessened, and the lens assumes a greater curvature. Behind the lens is a dark chamber, lined with a membrane, the choroid, which is deeply pigmented by a colouring matter of dark brown. This chamber, together with the smaller chamber in front of the lens, is filled with a clear semi-fluid or fluid substance, which serves to maintain the shape of the eyeball; and the whole eyeball is surrounded by a leathery protective membrane, the sclerotic, which is pierced behind by the optic nerve and

[1] Models of the brain and sense-organs are manufactured, in all degrees of elaboration, by a number of firms: Auzoux, Benninghoven & Sommer, Bock-Steger, Brendel, Deyrolle, etc. The writer uses, as eye-models, the *Œil complet de très grande dimension*, of the Auzoux series of clastic anatomy, and the models numbered 3 *b* and 3 *l* in the Benninghoven & Sommer series.

passes over in front into the transparent cornea. The retina, or sensitive film, is produced by the expansion of the optic nerve over the posterior two-thirds of the internal surface; it is self-renewing, just as the diaphragm and lens are automatic.

The retina, with which we are chiefly concerned, is a very thin but extremely complex membrane. Its terminal structures, which are the sensitive receivers of the physical light stimulus, are known as rods and cones. In general, these are intermingled over the entire retina. There are, however, two areas — the optic disc and the yellow spot — which show a different formation. The optic disc is the point at which the optic nerve enters the eyeball. Here there is no true retina, but a blind spot, whose situation and dimensions may readily be determined by experiment. The yellow spot or macula lutea lies at the posterior pole of the eyeball: it is peculiarly sensitive to form and contour, and is therefore termed also the spot of clearest vision. At the centre, in the fovea centralis, it shows a depression, where the retina consists of little more than a single layer of attenuated cones. The whole spot is coloured yellow, so that in macular vision the colours of the short-wave end of the spectrum are somewhat darkened. —

It is not possible, in the present state of our physiological knowledge, to give an entirely satisfactory explanation of all the facts of visual sensation. The following, however, seem to be the most reasonable hypotheses.

(1) *The Theory of Dual Vision.* — Many indications point to the conclusion that the rods are the end-organs of twilight, the cones the end-organs of daylight vision. That is to say, the rods are organs which, under stimulation

by light-waves whose energy is too low to stimulate the cones, furnish us with sensations of light. The blindness of the normal fovea at night-time is due to the fact that the retina is there composed only of cones. The Purkinje phenomenon, and the exceptions to the third law of colour mixture, are to be ascribed to the rods: they mean that the rods are affected by light-waves of different length otherwise than are the cones. The typical retina of the totally colour blind eye is a rod-retina, lacking functional cones, and the complete blindness of the fovea is a necessary result.

We have seen that twilight vision is extremely dependent upon dark-adaptation. It is significant, in this connection, that the terminal members of the rods contain a purplish red substance, the visual purple, which bleaches on exposure to light and is reformed under the influence of darkness. It is further significant that the distribution of tints in the Purkinje spectrum (lightest region in *G*) accords with the chemical action of the different light-waves upon the visual purple. Whether, however, the visual purple is essentially concerned in rod-vision, or whether it serves merely to sensitise the visual apparatus, cannot certainly be decided. The retinas of nocturnal animals — owls, bats, rats, moles — are almost wholly deficient in cones, while their rods are richly supplied with the visual purple. Animals whose eyes lack this rod-pigment — fowls, pigeons — are strictly diurnal in their habits.

(2) *The Phenomena of Daylight Vision.* — There are two current theories of daylight vision, called respectively the Helmholtz and the Hering theory. Both are adequate to a large proportion of the facts; both have been variously modified to accord with newly discovered facts; neither fits the facts in complete detail. Both, of course, are physiological theories; but Helmholtz approaches physiology by way of physics, Hering rather by way of psychology. The

following account agrees, in its main outlines, with Hering's view.

We assume that the retinal cones contain three visual substances, which are decomposable by light, and which are the vehicles of reversible or antagonistic chemical reactions. We may term them the black-white, the blue-yellow, and the red-green substances. The cones of the central area contain all three; those of the intermediate zone mostly contain the *Bk-W* and the *B-Y* substances; and those of the outermost zone mostly contain only the *Bk-W* substance. The latter, which is thus the most widely distributed of the visual substances, is affected by every light stimulus which exceeds a certain lower limit of energy; the other two are affected only by the wave-lengths corresponding to their names. The six chemical reactions which occur in the three substances give rise to the sensations of black, white, and the four invariable colours. From them and their combinations are derived, with a single exception, all the phenomena of daylight vision.

The exception is the sensation of neutral grey. Since this sensation may persist while the retinal organs are out of function, it must take its origin in the brain. We ascribe it to the molecular motion of heat in the cells of the visual cortex, and are thus able to explain both its constancy and its qualitative character.

According to this view, the retinal processes which arouse the sensations of *Bk* and *W*, *B* and *Y*, and invariable *R* and *G* are antagonistic and incompatible. If, for instance, by mixing a dark *B* and a light *Y* on the colour mixer, we expose a certain area of the intermediate zone to light which affects the *Bk-W* and the *B-Y* substances in equal and opposite ways, no retinal sensation will be set up by the stimulus; we ought, so to speak, to see

nothing whatever. What we do see is a middle grey, the grey which is to be referred to the cortex. This grey, which mixes with all retinal sensations, is constant, because the heat-energy of the cortex is constant; it is grey because, unlike the sensations of light from the retina, it derives simultaneously from both of the antagonistic *Bk-W* reactions: — such a simultaneous occurrence of opposed processes is, as physics tells us, precisely the effect produced by heat within a body which is in chemical equilibrium. The office of the cortical grey is to prevent the darker objects in the field of vision from being drowned out by their lighter surroundings.

The facts of indirect vision are explained by the distribution of the visual substances over the retina. The *Bk-W* is, evidently, the oldest, the *R-G* the youngest, of the three. Hence the *R-G* is also the most instable. In cases of partial colour blindness, it does not occur at all, while the *Bk-W* and the *B-Y* substances are intact. If the light-waves possess a very high degree of energy, it is thrown out of function (§ 16).

The facts of colour mixture may easily be worked out in terms of the three retinal substances and the cortical grey. Take, for instance, the fact that *C* and *BG*, mixed in the right proportions, give grey. The stimuli affect the *R-G* substance in equal and opposite ways. They also affect the *Bk-W* substance: perhaps equally and oppositely, perhaps both by way of *Bk* or both by way of *W*, perhaps differently, so that the one of these antagonistic processes is stronger than the other. In the first case we see simply the cortical grey; in the second, a distinctly dark or a distinctly light grey; in the third, a slightly dark or somewhat light grey, according as the retinal excess has fallen on the side of *Bk* or of *W*. The same sort of analysis may be carried through for the mixture of other light stimuli, in any number and of any wave-length.

To account for contrast, we have merely to suppose that the retinal substances tend towards equilibrium over the whole area of their distribution, so that, directly affected at one point, they are indirectly — and oppositely — affected at all other points, though most noticeably, of course, in the immediate neighbour-

hood of the stimulus. If we look at a red square on a grey ground, we see at once the contrast-fringe of verdigris; it is as if the whole of the *R-G* substance were up in arms to repel the invasion. The same thing holds of other stimuli, including *Bk* and *W*; all alike call out, indirectly, the antagonistic retinal process.

Lastly, the phenomena of adaptation and after-image follow from the antagonistic character of the reactions in the three substances. As we gaze at the red square, the *R*-reaction of the *R-G* substance is gradually reduced; or, what is the same thing, the *G*-reaction is gradually strengthened. Presently, the two reactions are of equal strength; adaptation to the coloured stimulus is complete, and we see grey. If, now, the red square is removed, the *G*-reaction is suddenly given the ascendancy, and shows itself in the complementary colour of the after-image.

References for Further Reading

§§ 14–22. The dual theory of vision was first propounded by the histologist M. J. S. Schulze in 1866 (*Zur Anatomie und Physiologie der Retina*, in *Archiv für mikroskopische Anatomie*, ii., esp. 255 f.). Its establishment in recent years has been largely due to the work of J. von Kries, professor of physiology in the University of Freiburg i. Br., who has described it in the chapters entitled *Die Gesichtsempfindungen*, in W. Nagel's *Handbuch der Physiologie des Menschen*, iii., 1905, 109 ff. Here will also be found a full statement and criticism of the Helmholtz and Hering theories. For the Helmholtz theory, and its debt to Thomas Young, see H. L. F. von Helmholtz, *Handbuch der physiologischen Optik*, 1896, esp. §§ 20, 23. The theory of E. Hering, who is now professor of physiology in the University of Leipzig, is set forth in *Zur Lehre vom Lichtsinne*, 1874, and *Grundzüge der Lehre vom Lichtsinn*, pts. i., ii., 1905, 1907 (not yet completed). The cortical origin of the sensation of grey was suggested by G. E. Müller, professor of philosophy at Göttingen, in *Zur Psychophysik der Gesichtsempfindungen* (offprinted from *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*), 1897. — Consult also W. H. R. Rivers, *Vision*, in *E. A. Schäfer's Text-Book of Physiology*, ii., 1900, 1026; art. *Vision*, in *J. M. Baldwin's Dictionary of Philosophy and Psychology*, ii., 1902, 765 ff.; I. M. Bentley, *The Simplicity of Colour Tones*, *American Journal of Psychology*, xiv., 1903, 92; J. W. Baird, *The Colour Sensitivity of the Peripheral Retina*, 1905.

AUDITION

§ 23. **The Auditory Qualities.** — The world of sound, like the world of sight, is made up of two classes of sensations, the one variegated and of manifold quality, the other sober and monotonous. These are distinguished, in ordinary speech, as tones and noises. Tones, which correspond to the senations of colour, are the proper material of music; they have a certain clarity and stability which fit them for their place in art. Noises, which correspond to the sensations of light, are dull and instable; if momentary, they are abrupt and harsh, if continued, they are rough and turbid. And as in vision, so in audition, the two kinds of sensation are in some measure independent, while at the same time they are intimately related.

We are apt to think of tones as coming from a musical instrument, piano or violin. Musical tones are, however, complicated mixtures of tones and noises (§ 25). To obtain sensibly pure tones, elementary tonal processes, we must have recourse to special apparatus: the best are weakly sounding tuning-forks standing on their resonance boxes, and weakly blown bottles. If we

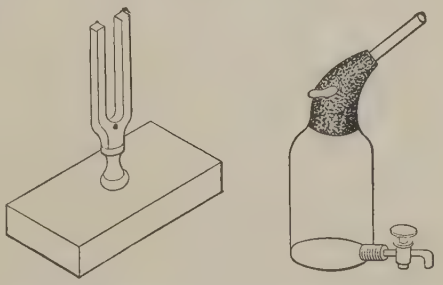

FIG. 11. Tuning-fork on Resonance Box, and Glass Bottle, fitted with mouthpiece for blowing. The pitch of the bottle-tone may be raised or lowered by pouring in or letting out water.

work through a long series of such pure tones, we notice, first, that they differ qualitatively as high and low; they show differences of pitch. These terms are, of course, spatial in origin, and it is not altogether easy to see how they came to be applied to tonal qualities.[1] At any rate, they are in current use, and we understand their meaning. We notice, secondly, that the tones differ qualitatively in what we must call — again in spatial terms — size or diffusion. This attribute runs, in general, parallel with the attribute of

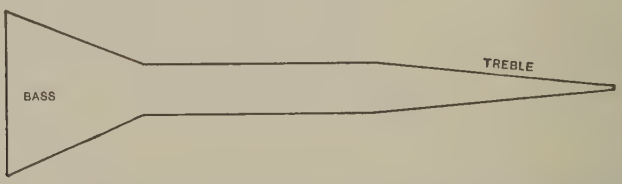

FIG. 12. The Tonal Pencil, representing the sum-total of tonal qualities, as the Colour Pyramid represents the sum-total of visual qualities. The horizontal dimension corresponds to the attribute of pitch, the vertical to the attribute of volume.

pitch; but at the ends of the scale it changes more quickly, in the middle region more slowly, than pitch, so that deep tones appear very large and diffuse, and high tones very small and concentrated, while the intermediate tones seem all to be more or less of the same size.

As we have already said (§ 11), some psychologists believe that tones have a truly spatial attribute of volume, while others think that the low tones merely remind the hearer of large things and the high tones of small. This second view contains, undoubtedly, a good deal of truth. The deepest tones from the organ, for instance, are not only heard, but are also felt as a thrill over the

[1] The composer Berlioz remarked that, on the piano, high means right and low means left in the horizontal plane; and that, if the violinist's hand rises, for high tones, the cellist's drops. The whole question is discussed by C. Stumpf, *Tonpsychologie*, i., 1883, § 11.

whole body; and the size of musical instruments varies with the height of their tones. Children call deep and high tones big and little, old and young: evidently because the former come from the large grown-up people, and the latter from their small playmates. At the same time there can be no doubt that what we have termed diffusion and concentration is an inherent attribute of tones; only, we need no more regard it as really spatial than the other attribute of height or pitch. In trying to specify the ultimate characters of sensation, we have to take language as we find it, and to use metaphor and analogy. We speak of colour-tone and of colour-depth, but we do not mean that the hues sound differently, or that we can drop a stone into them. So we shall speak presently of tone-colour, without implying that tones are red or green. Pitch and size stand for certain qualitative aspects of tonal sensation, and neither can be understood literally in terms of space. —

There seems, in the musical scale, to be a periodical recurrence of tonal quality; the corresponding notes of successive octaves, if struck together, sound in unison. It has therefore been suggested that the tonal system must be represented, not by a straight line, but by a line which returns upon itself, a spiral line. This resemblance of a note to its octave is not, however, a matter of pure sensation; it depends upon conditions which we discuss in Pt. II. If the finger is run in a glissando over the white keys of the piano, the impression obtained is that of a linear series of tonal qualities. Hence our sensations of tone may be represented by a straight line which tapers, in three divisions, from bass to treble, being broadest for the diffuse deep tones and narrowest for the small and concentrated high tones.

The noises that we hear in everyday life are of two kinds, explosive and continuative. For the former, we have such words as crack, pop, snap; for the latter, such words as hiss, sputter, rumble. It seems, at first thought, that the continuative noises might very well be regarded as repeated explosions; a rattle or clatter, for instance, is

simply a quick succession of raps or shocks. This reduction cannot, however, be carried through. Such noises as the hiss of escaping steam, the soughing of wind in the trees, the rustle of a newspaper, — complex as they certainly are, — refuse to be analysed by introspection into series of explosions; and in the pattering of rain, or the sizzle of frying fat, we distinguish the rapidly recurring taps or clicks from the steady hiss of the background. There are, then, two types of noise sensation, the snap and the hiss, to be set alongside of the sensations of tone.

There can be no question that sensations of tone may be had without accompanying noise. It is much more difficult to decide whether sensations of noise occur without accompanying tones. In the first place, all explosive noises have a certain, more or less definite pitch. A hand-clap sounds lower than a snap of the fingers, the crack of a rifle lower than the spit of a revolver. This statement holds of the simplest noises that we can produce in the laboratory. Thus, if soap-bubbles are filled with a mixture of air and hydrogen, and touched off with a match, the large bubbles give a deeper pop than the small. Or if tuning-fork tones are cut down to mere momentary puffs of sound, we hear short, dry strokes which are deeper for the large forks than for the small. It would seem that, in such cases, we are listening to simple, toneless noises, — in which event we must say that these noises show differences of pitch akin to the pitch-differences of tones, though of a coarser kind. But there is an alternative. If a bar of wood is dropped upon a wooden table, we hear a thud which sounds merely noisy. If, however, we drop a series of bars, cut to the right lengths, we hear, over and above the noise, a series of definite tones, an air played in a certain key. The single thud contains a true tone, but a tone of such short duration that introspection fails at first to find it. And the same thing may be true of the noises from the soap-bubbles and the tuning-forks. If, again, we pass the finger-nail slowly over the ribbed binding of a

book, we hear a succession of plucks or taps; but, if we move more quickly, a distinctly tonal scroop. The pitch of the separate taps may, then, itself have been tonal.

In the second place, it seems safe to say that no continuative noises are known which do not contain recognisably tonal elements. The buzz of voices in a crowded room, the beat of waves upon a beach, the scrape of a book against others as it is returned to the shelf, the whisper of an *S*, the drag of matting over a floor, all alike contain various tones which can be singled out by the trained ear.[1] And, contrariwise, a continuative noise may be generated from a medley of tonal stimuli. If you press down, all together, an octave of notes in the bass of a piano, — better still, if you press suddenly upon the loud pedal, without striking the keyboard, — you hear a harsh, booming or rumbling noise with but little trace of tone.

In fine, introspection distinguishes between tones and noises; and, among noises, distinguishes such things as hiss, murmur, sigh, purl, crash, rumble from such things as snap, puff, knock, clack, roar. But we have, as yet, no means of determining with accuracy the nature and number of the elementary noise qualities.

§ 24. **The Dependence of Auditory Sensation upon Wave-number of Sound.** — Sound-waves, like light-waves, differ in respect of wave-length, wave-amplitude or energy, and wave-form or composition. We are not here concerned with their energy, since this has no influence upon the quality of auditory sensation. And we shall speak, not of wave-length, but rather of the wave-number — the number of complete waves in the 1 sec. — which is definitely correlated with it. As referred to the tones themselves, this is usually termed pitch-number; as referred

[1] Stumpf narrates that, in listening to a mountain brook, he heard a clear and steady tone of $f^{1}\sharp$, with neighbouring tones playing about it; further, a clucking and gurgling, made up of momentary deeper tones; and behind all the noisy plash which could not be analysed. *Tonpsychologie*, ii., 1890, 502.

FIG. 13. The Series of Auditory Qualities. The keyboard of a grand piano extends from the A_2 of 27.5 vs. to the c^5 of 4224 vs. The smaller piano keyboard ranges between the C_1 of 33 vs. and the a^4 of 3520 vs. Helmholtz' lower limit of orchestral music is the E_1 of 41.25 vs. (double bass); his higher limit, the d^5 of 4752 vs. (piccolo flute). The organ has a range of 9 octaves: C_2 (16.5 vs.) to c^6 (8448 vs.). The highest note of the violin is the e^4 (2640 vs.). The range of audition is, approximately, from the G_8 of 12.35 vs. to the f^8 of 45056 vs.

to the motion of sonorous bodies, it is termed vibration-rate.

Wave-number determines the quality, the pitch and size, of tonal sensations. The tones of the musical scale range between the limits of about 40 and 4000 vs. in the 1 sec. The range of audible tones is much wider, from about 12 to about 50000 vs. Between these extremes the trained ear can distinguish some 11000 different tones.

Wave-number also influences the intensity of tonal sensations. High tones are intrinsically loud, and low tones intrinsically weak, — very much as, in the spectrum, *Y* is a light and *V* a dark colour.

The three attributes of pitch, size and intensity, in so far as intensity is dependent not on energy but on pitch-number, constitute together what is known as tone-colour. High tones have a lighter or brighter, low tones a darker or duller colouring. Where we are dealing with relatively simple tones, the introspective analysis of tone-colour is not very difficult. The single term becomes useful, however, when we are considering the compound tones employed in music.

Over the greater part of the musical scale — from the lowest tones to tones of about 3000 vs. — two complete sound-waves suffice to arouse a tonal sensation, while stimuli of less than two

waves give rise to a snap or stroke. Physically, then, this explosive noise is merely an incomplete tone. The probable character of noise stimuli in general is discussed in the following § 25. —

The lower limit of tonal hearing may be determined by means of tuning-forks or of a steel lamella. Giant tuning-forks have been constructed, which vibrate very slowly; the rate of vibration may be varied by the adjustment of sliding weights upon the tines. The weighted wire forks, a specimen of which is shown in Fig. 14, are more manageable. The lamella is a blade of soft steel, clamped in a wooden vise, and actuated by the finger; a scale engraved on the blade indicates the rate of vibration.

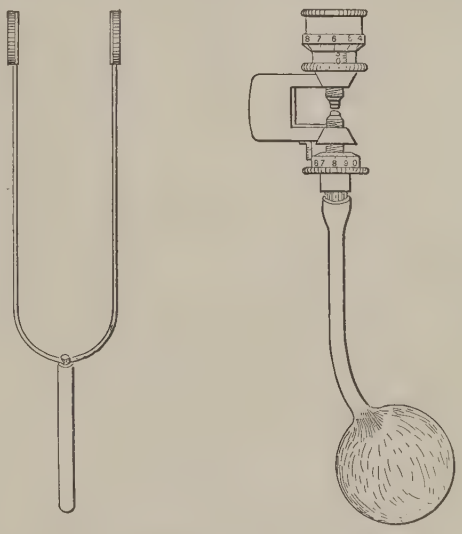

FIG. 14. Weighted Wire Fork and Galton Whistle.

The upper limit may be determined by means of very small tuning-forks, actuated by a bow, or more easily by means of the Galton whistle shown in Fig. 14. The whistle is a very small stopped labial pipe, actuated by the squeeze of a rubber bulb, and closed by a piston which is adjustable by a micrometer screw.

The series of distinguishable auditory qualities, between the upper and lower limits, may be worked out in part by means of a set of weighted wire forks and of a Galton whistle. For the middle region of the scale we may use a tonometer: a series of delicately adjusted tuning-forks, or a series of metal tongues of minimally different lengths thrown into vibration by a bellows. A less expensive apparatus is the Stern variator shown in Fig. 15. This consists essentially of a blown brass bottle, whose pitch may

be varied, little by little, through the introduction or withdrawal of mercury.

§ 25. **The Dependence of Auditory Sensation upon Composition of Sound.** — The train of sound-waves which arouses a sensation of tone is a periodic vibration of simple harmonic form; the motion of the air-particles is a simple pendular motion. Periodic vibrations of any other form may be analysed, mathematically, into a series of superposed simple harmonic vibrations, whose wave-numbers are multiples of the wave-number of the given vibration. That is to say, the complex wave may be regarded as made up of a group of simple waves, whose wave-numbers — if the wave-number of the complex wave is taken as 1 — stand in the ratios 1 : 2 : 3 : 4, etc. All musical tones or, as we may call them, compound tones are aroused by trains of waves of this complex kind.

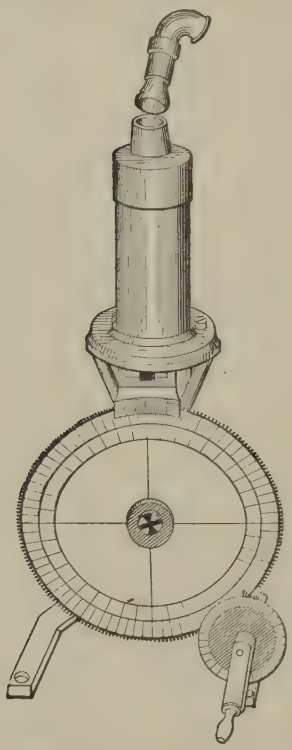

FIG. 15. Stern's Variator.

The ear, unlike the eye, is an analysing organ; and it is therefore possible, within limits and after practice, to single out the simple tones which together constitute the compound tone, — to repeat in sensation the analysis already performed by mathematics. The compound tone then splits up into partial tones, the lowest of which is

termed the fundamental, and the rest the upper partials. Sometimes the upper partials are distinguished as the overtones of the fundamental: this usage is a little confusing, since the second partial becomes the first overtone, and so on. The partial tones, when thus singled out by the attention, have the simple character of the tones produced by tuning-forks or blown bottles; they sound, that is, as pure tones, and do not differ with the different instruments from which they come.

Most of us, however, lack the training, and some lack the ability, to resolve a compound tone into its simple components. Under these circumstances, the tone is itself heard as simple, but has upon it a certain colouring or timbre, which varies with the various instruments. The tone of the organ is full and rich, that of the trumpet is hard and rasping, that of the clarinet is hollow and nasal. These differences of timbre are primarily due to the differences in the number and relative intensity of the overtones which accompany the fundamental.

A musical instrument consists essentially of a vibrating body — plate, rod, string — and a resonance chamber; a tuning-fork on its resonance box offers a simple illustration. The complexity of the air-waves which it sends to the ear may be variously produced. The vibrating body may, like the piano string, be so constituted as to vibrate in halves, thirds, quarters, etc., at the same time that it vibrates as a whole. Or it may be forced into complex movements by the manner in which it is actuated; thus the violin string vibrates as a whole, but also zigzags back and forth as it is drawn forward by the bow and slips away again. Or, lastly, it may vibrate as a simple pendulum, and yet not impart a pendular movement to the air-particles; the metal tongue, for instance, vibrating in an opening which it almost fills, gives rise to extremely complicated motions of the surrounding air. When

all these possibilities are taken into account, it is not surprising that even relatively pure tones should be of rare occurrence.

The timbre of the compound tone is, in the main, the unanalysed resultant of the tone-colours of its simple constituents. Bearing in mind the nature of these tone-colours, we have no difficulty in explaining the timbre of most musical instruments. A piano tone, for instance, necessarily sounds brighter — and therefore, to the untrained ear, higher — than a flute tone of the same pitch, because it contains a longer series of overtones. These are, of course, progressively higher than the fundamental; and high tones have a bright tone-colour. The full and rich tones of open organ-pipes, piano and French horn are due to the presence, at moderate intensity, of the first half-dozen partials. The harsh and penetrating tones of trumpet, bassoon, harmonium are due to the predominance of the higher overtones. The tone of the clarinet contains only the odd-numbered partials. Its nasal character must probably be ascribed to the presence of beats (§ 26) and to the fact that the difference-tones (§ 27) produced by the partials do not coincide with the constituent simple tones.

If we extend the meaning of timbre to cover everything that helps us to distinguish the tones of the different musical instruments, we must further mention, in the first place, the different noises that accompany them. The scrape of the violin, the pluck of the banjo, the thud of the piano, the sish of the wind instruments, are characteristic. So also is the manner in which the tones enter consciousness; the large brass instruments lumber into hearing, the flute glides in. Other criteria are pitch, intensity, variability, and mode of performance. An instrument that moves in the c^5-octave can hardly be anything else than a piccolo; an instrument that sounds at a certain loudness must be a trumpet. The oboe is distinguished by a peculiar delicacy of dynamic shading. Lastly, many instruments have peculiar features of melody or harmony, rhythm or modulation, so that they may be identified by the nature of their performance. We can hardly think of flute, harp, trumpet, without at the same time thinking

of the special way in which they are played, or the special use to which they are put in orchestral music. —

It is sometimes said that tonal stimuli are periodic, noise stimuli aperiodic movements of the air-particles. But, on the one hand, aperiodic vibrations may produce tonal sensations, as in the 'rising tone' of the siren; and, on the other, a periodic vibration of short duration or a mixed medley of periodic vibrations may, as we have seen, produce noise. The air-shock ordinarily caused by an explosion is probably a periodic system of many, slightly different wave-numbers and of rapidly decreasing intensity; so that, from the physical point of view, the crack or roar is a mixture of incomplete compound tones. In the same way, the continuative noise is probably due to a very large number of vibrations, differing relatively little in periodicity but widely in duration. Physically, that is, the hiss must be regarded as a mixture of compound tones, both complete and incomplete. This physical likeness of noise and tone stimuli, which enables them to act upon the same sense organ in much the same way, accounts for the introspective difficulty of distinguishing the tonal and the noisy elements in many instances of auditory sensation.

§ 26. **Beats and Intermediate Tones.** — Tones are intrinsically harmonious, as colours are intrinsically antagonistic. It is this character of tonal sensations which, as we shall see later, has determined the choice of notes in the musical scale and the development of music as melody and harmony. In the meantime, we must take account of two sensory phenomena which result from the blending of tones: the production of beats and intermediate tones, and the production of what are called combinational tones. —

If two tones of precisely the same pitch-number are heard at the same time, the resulting sensation differs from its constituents merely in the attribute of intensity. When the trains of air-waves are so timed that crest coin-

cides with crest and valley with valley, it is stronger than the single tone; when the crests of the one train overlap the valleys of the other, it is weaker.

If, now, the one of the two simultaneously sounding tones is mistuned, so that its pitch-number is somewhat raised or lowered, the resulting tone is no longer smooth and continuous, but shows rhythmical fluctuations of intensity, which are known as beats. So long as the mistuning is slight, the beats are slow; the tone surges up to its maximal intensity and gradually subsides again. With increasing difference of the generating tones, the beats become quicker and quicker. At the same time they grow harder and less billowy, so that they may be compared to the rattle of a kettle-drum, or even to a rapid succession of hammer-strokes upon an anvil. As the pitch-numbers diverge still further, the separate beats give place to an unanalysable roughness, harshness or hoarseness, which with yet wider separation of the generators finally disappears.

The number of beats produced in the 1 sec. is always equal to the difference between the pitch-numbers of the generating tones. For suppose that we are listening to tones of 100 and 101 vs., and that the two trains of air-waves start in the same phase. At the end of the first half-second, the tone of 101 vs. will be exactly half a vibration in advance of the tone of 100 vs.: crest will coincide with valley, and the resulting tone will be weakened. At the end of the second half-second, the tone of 101 vs. will be exactly one complete vibration in advance of the other: crest will coincide with crest, and the resulting tone will be strengthened. We hear, therefore, one beat, one intensive fluctuation, in the 1 sec.; and $101 - 100 = 1$. The same rule will evidently hold for any other pair of generating tones.

Beats are easily distinguished and counted when they occur at

the rate of 3 or 4 in the 1 sec. They may be followed, by a practised ear, from a lower limit of 1 in 180 sec. to an upper limit of some 20 or 30 in the 1 sec. At this point, however, the complex is already becoming rough. The impression of roughness or harshness is more pronounced and more persistent in the high than in the low regions of the tonal scale. Thus, the tones *CG*, *Gc*, *ce*, *eg*, c^1d^1, d^1e^1, b^1c^2 produce, all alike, 33 beats in the 1 sec.; but the roughness is increasingly marked as the pitch-numbers grow larger. Similarly, the transition from harshness to smoothness occurs in the great octave at about 40, in the four-accented octave only at about 400 beats in the 1 sec.

The surging beats which proceed from a very slight difference of pitch-number are heard as fluctuations of a single tone, whose pitch is indistinguishable from that of the generators. As the difference increases, the single beating tone may be recognised as an intermediate tone, which at first lies near the lower generator, and gradually rises in pitch until it approaches the upper. With a certain amount of difference (in the once-accented octave, a difference of the musical interval of the major second), the two generating tones may be heard alongside of the intermediate tone. The upper generator now appears, with occasional intermissions, as a smooth and continuous tone: the intermediate tone, which carries the beats, begins to take on a noisy character: the lower generator, whose identity is somewhat obscured by the presence of difference-tones (§ 27), is less stable than the upper, but seems in general to have little or no share in the production of the beats. Finally, after this stage has been passed, the intermediate beating tone loses its tonality, and we hear the two generators as separate tones, accompanied by a continuative noise, — the harshness or roughness mentioned above.

The gross phenomena of beats may readily be demonstrated by means of tuning-forks, blown bottles, etc. To distinguish the generators above and below the beating intermediate tone is, however, by no means easy, and requires special practice. This intermediate tone, it may be remarked, is of physical origin; under certain conditions, the superposition of two pendular vibrations of nearly the same wave-number gives rise to a resultant vibration of intermediate wave-number.[1]

If compound tones are sounded together, beats may arise between their overtones. Under certain circumstances, the overtones of a single compound tone may also beat with one another. Thus, in the case of the *C* of the harmonium, the partial tones from the seventh (b^1) onwards are sufficiently near and sufficiently strong to produce sensible beats.

§ 27. **Combinational Tones.** — If we sound together two precisely similar tones from the upper region of the tonal scale, and slowly mistune the one without changing the other, we shall hear, according to the statements of the previous section, first a single smooth tone, then a surging, and presently a hammering tone. When the beats have reached a frequency of some 30 in the 1 sec., we hear an entirely new, very deep tone, whose pitch-number corresponds to the difference between the pitch-numbers of the two generators. If we term the upper generating tone u, and the lower l, we hear, in general, a third tone whose pitch-number is $u - l$. This is known as the first difference tone, D_1. Under favourable circumstances, a single pair of tones will give rise to no less than five difference tones, whose pitch-numbers correspond to the successive differences between the pitch-numbers of the lowest tones present in the complex. Thus, let u be a tone of 1328 and l a tone of 1024 vs. (c^3). Then we have

[1] Rayleigh, *The Theory of Sound*, i., 1894, 49, 71; ii., 1896, 443, 450.

$$D_1 = \qquad u - \quad l = 304$$
$$D_2 = \quad l - D_1 = 2\,l - \quad u = 720$$
$$D_3 = D_2 - D_1 = 3\,l - 2\,u = 416$$
$$D_4 = D_3 - D_1 = 4\,l - 3\,u = 112$$
$$D_5 = D_1 - D_4 = 4\,u - 5\,l = 192$$

all of which may be rendered audible to the practised ear.

Difference tones may be demonstrated by means of high forks, Galton whistles, Quincke tubes, a double bicycle whistle, etc. To hear them, one must neglect the high tones of the instruments, and listen for something lower and larger. Sometimes the difference tone seems to be diffused through the room, like the humming of a top; sometimes it seems to be a deep booming within the ear. A very striking demonstration may be given with two Galton whistles, the one of stationary and the other of varying pitch. Since a difference of a certain number of vs. means a much wider interval in the region of the difference tone than in that of the generators, a slight change of the whistle will produce a pronounced change in the difference tone, which accordingly sounds as the howling of the wind, or as the tone of a fog-siren. — To hear the whole series of difference tones requires special training.

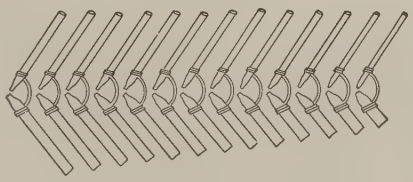

FIG. 16. Set of Quincke Tubes.

The difference tone, unlike the intermediate tone of the preceding section, cannot be obtained by the superposition of pendular vibrations. It must, therefore, if it exists outside the ear at all, be set up by some secondary vibration of the sonorous body. Objective difference tones are, as a matter of fact, generated by instruments, like the harmonium, in which the two primary tones are produced by the same air-blast, and by certain forms of vibrating membranes. The great majority of difference tones are, however, subjective, — ear tones and not air tones. They are occasioned by the mechanism of the ear itself.

It is noteworthy that difference tones behave, in tonal complexes, precisely as their generators. A difference tone, that is, may beat with another difference tone or with a generating tone; and two difference tones, or a difference tone and a generating tone, may give rise to an intermediate tone and to new difference tones. So far as hearing is concerned, the difference tones are on an equality with the tones aroused by air-waves.

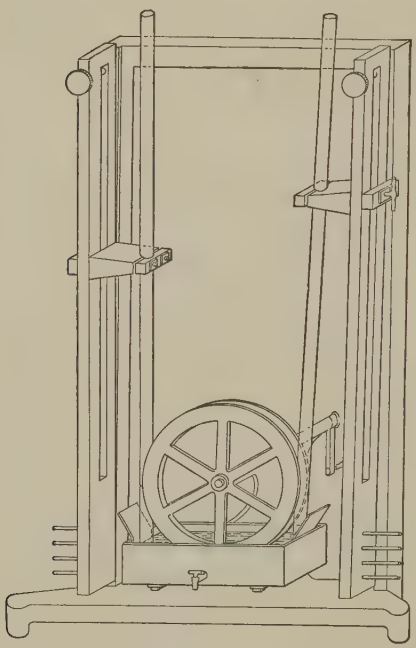

FIG. 17. R. Koenig's Apparatus for the Demonstration of Difference Tones. — *Quelques Expériences d'Acoustique*, 1882, 165.

Difference tones have been known to science since the middle of the eighteenth century. In 1856, Helmholtz announced the discovery of another kind of combinational tone, which he named the summation tone; its pitch-number is $u+l$, the sum of the pitch-numbers of the two generators. The summation tone is faint, and difficult to distinguish; indeed, many investigators have questioned its existence. Recent observations seem, however, to leave little doubt that Helmholtz' statement is correct.

It has been suggested, in particular, that the summation tone is simply a difference tone of a higher order, generated by the first overtone of u and the first difference tone; for $2u-D_1=2u-(u-l)=u+l$. As, however, an objective summation tone is

produced and produced only by those instruments which produce objective difference tones, it is clear that the physical conditions for the arousal of the two kinds of combinational tones are the same. And as the ear has shown itself able to originate difference tones, we may naturally suppose that it can also originate the summation tone. Moreover, the presence of the summation tone has been recorded under circumstances which seem to preclude the possibility of its generation by an overtone. Owing to its faintness, it is much less important, psychologically, than are the difference tones.

§ 28. **Theory of Audition.** — Sound-waves are received into the outer ear-passage, and impinge upon the tympanic membrane or drum-skin, which forms the boundary between the external and the middle ear.[1] The vibrations of this membrane are transmitted by the auditory ossicles, with diminished amplitude of excursion but increased energy, to the oval window. Here they are transferred to the lymph with which the internal ear is filled.

The cochlea of the internal ear, with which, as the end-organ of hearing, we are here concerned, is a structure of great complexity. If we unroll it, we have a long inelastic tube, filled with water; both ends are closed, but the one end contains two windows, filled with elastic membranes, — the oval window above and the round window below. Between the windows lies a horizontal shelf or partition, which divides the tube into an upper and a lower half, and

[1] The author uses, as ear-models, the Auzoux *Oreille de très grande dimension;* the model numbered 4 *b* in the Benninghoven & Sommer series; a pair of very large models of the internal ear, from the Bock-Steger series (these seem not to have been advertised of late years, but are probably still procurable; they are excellent for purposes of demonstration); and Helmholtz' model of the middle ear. Natural preparations of the temporal bone, and casts of these preparations (with enlarged models of the ossicles), may also be obtained. The Ludwig or Merk model of the organ of Corti is useful for a detailed demonstration.

which extends throughout almost its whole length. The partition, which we may conceive of as a long narrow rectangle, consists partly of bone and partly of membrane. The bone is widest at the windows and narrowest at the far end of the cochlea; the membrane forms a triangle with its apex at the windows. This triangular membrane, known as the basilar membrane, carries the hair-cells with which the fibres of the auditory nerve are connected, and which thus correspond to the rods and cones of the retina. Finally, the upper half of the tube is subdivided by a membranous cross-partition, stretched obliquely between the oval window and the hair-cells, as if to protect these from the direct impact of the waves set up by the push of the ossicles.

We have seen that the ear is an analyser, that it is able to split up a compound wave-motion into simple pendular vibrations, or to resolve a compound tone into simple partial tones. According to the theory of Helmholtz, this analysis is performed by the basilar membrane. Histologists tell us that the membrane is composed, in essentials, of a large number of cross-fibres — variously estimated at 13400 to 24000 — which range in length from 0.041 to 0.49 mm., a ratio of 1 : 12. The fibres represent a system of stretched strings, like those of a harp or a piano, and will accordingly respond by vibration to the wave-movements to which they are tuned. Suppose, then, that a wave-motion of a certain frequency is set up at the oval window. The motion is transmitted, through the membranous cross-partition, to the basilar membrane. A certain basilar fibre (the fibre whose natural period of vibration is the same as that of the incoming wave) is set vibrating; this vibratory movement is imparted to the hairs of the cells which rest

upon the fibre; and the agitation of the hairs acts as stimulus to the fibrils of the auditory nerve. The wave-motion, having thus done its work upon the basilar membrane, spends itself at the round window, and the whole system comes to rest again.

The Helmholtz theory regards the fibres of the basilar membrane as resonators, and is therefore known as the resonance theory of audition. Just as the strings of a piano respond selectively when a tone is sung into the instrument, so do the basilar fibres vibrate in sympathy with the wave-motion which corresponds to their natural period of vibration. The tuning of the fibres and their selective response to stimulus must not, however, be thought of as absolute. Neighbouring basilar fibres differ but little in length, and are closely bound together. Hence we must suppose that, if a simple pendular vibration is set up at the oval window, it is not a single fibre but rather a narrow strip of the basilar membrane which falls into sympathetic vibration. The sensation of simple tone results from the agitation of the hairs of a little group or field of hair cells.

To account for the sensation of noise, we need only assume that a broader strip, or perhaps that several broad strips of the basilar membrane at the same time are thrown into brief vibration. The compound tone will be produced by the simultaneous vibration, at different amplitudes, of a number of narrow strips, each one of which, if it vibrated alone, would give us the sensation of a simple tone.

To account for beats, we must suppose that the strips set in motion by the two generating tones partially overlap. So long as the generators are near together, we hear only a single tone, — the intermediate tone, due to the superposition of the primary vibrations. The portions of the strips which do not overlap are so small that they cannot vibrate independently and give rise to independent tonal sensations. The beating of the intermediate tone results from the interference of the different oscillatory motions impressed upon the fibres. As the generators diverge, we

hear them sounding smoothly above and below the beating intermediate tone. It is now only a comparatively small portion of the vibrating strips that overlaps; so that the major portions on either side vibrate singly, each in its proper period, and consequently arouse each its proper sensation of tone.

Helmholtz himself explained combinational tones as due to the movements of the drum-skin and ossicles. Attempts have since been made to derive them from the vibration of the basilar fibres; but recent investigation seems to show, pretty conclusively, that Helmholtz was right, and that these tones take their physical origin in the middle ear.

There is nothing in audition that is analogous to colour blindness in vision. On the other hand, the resonance theory receives strong support from pathology. Cases are known in which, while the outer and middle ears are intact, the range of hearing is greatly reduced: all that is left of the tonal scale is a tonal 'island,' extending perhaps over a couple of octaves, perhaps only over two adjacent semitones. Other cases occur in which the range of hearing is normal, but the tonal scale is not continuous; there are tonal 'gaps,' large or small,— parts of the scale where the patient is completely deaf to tonal stimuli, though he can perfectly well hear the tones above and below. Both of these defects of hearing point to the existence, in the internal ear, of a series of end-organs that are separately stimulable by tones of different pitch-number; and end-organs of this sort are provided by the basilar fibres and the hair-cells which they support.

The principal objection urged against the Helmholtz theory is that the basilar fibres are too minutely small to serve as resonators, especially for the tones of the lower region of the scale. To this the reply is made that they are loaded, by the arches of Corti and the adjacent cells, and that their frequency of vibration is thus very considerably reduced. We cannot at present say either that the objection is fatal to the theory or that the reply is convincing in its favour. No other theory has, however, been proposed which covers so wide a range of facts or explains these facts so satisfactorily as the resonance theory.

References for Further Reading

§§ 23–28. A general summary of facts and theories is given by K. L. Schaefer, professor of physiology at Berlin, in Nagel's *Handbuch*, iii., 1905, 476 ff. More detailed treatment of the subject will be found in the *Tonpsychologie* of C. Stumpf, professor of philosophy at Berlin. On the character of auditory sensations at large, see i., 1883, §§ 10, 11; ii., 1890, § 28: on tone-colour and timbre, ii., § 28: on beats, ii., § 27: on combinational tones, ii., 243 ff., and other passages cited in the index. Another classical work is Helmholtz' *On the Sensations of Tone*, translated by A. J. Ellis, 1895. Parts i. and ii. deal with the subject-matter of these sections; the author's theory is worked out on pp. 128 ff., 158. — Consult also A. Barth, *Zur Lehre von den Tönen und Geräuschen*, in *Zeitschrift f. Ohrenheilkunde*, xvii., 1887, 81; art. *Hearing*, in *Baldwin's Dict.*, i., 1901, 443 ff.; W. Wundt, *Physiologische Psychologie*, ii., 1902, 63 ff., 370.

It has been known for some time that the vowel-sounds of the human voice owe their timbre, not to a regular series of overtones, but to certain concomitant tones, whose pitch remains relatively constant whatever the fundamental may be upon which the vowel is spoken or sung. These tones, called by L. Hermann 'formants,' apparently represent the proper tones of the buccal resonance chambers; they are usually inharmonic both to the fundamental and to one another; and they may attain to a high degree of intensity. Recent investigations, now, seem to show that the timbre of the wind instruments may also be due to the presence of formants: "instead of a characteristic series of harmonics, it seems that each instrument possesses rather a characteristic tone or tones . . . of constant pitch for all notes of its scale" (D. C. Miller, *Science*, N. S., xxix., 1909, 171; cf. R. Wachsmuth und G. Meissner, *Arch. f. d. gesammte Physiologie*, cxvi., 1907, 543; E. Herrmann-Goldap, *Annalen d. Physik*, xxiii., 1907, 979). If this result is confirmed, the account given of timbre in § 25 must be correspondingly modified.

SMELL

§ 29. **Sight and Hearing: Taste and Smell.** — If you were asked to make out a list of the senses, you would probably begin with sight and hearing. These two seem, naturally, to go together: they are the 'higher' as contrasted with all the other, 'lower' senses. The word 'higher' may then mean one of two things: that the sense-organs, eye and ear, have attained to the highest degree of biological development; or that the sensations derived from them are put to the highest intellectual purposes. The second meaning is, perhaps, that which is the more familiar to common sense. Sight and hearing have an obvious twofold value to the organism: a commercial value, as the vehicle of communication, of written and spoken language; and a cultural value, as the vehicle of the fine arts, painting and sculpture, literature and music.

From this point of view, the bracketing together of sight and hearing is both natural and right: only, of course, while we talk in terms of common sense, we must think in terms of parallelism. On the other hand, it is worth while to remember that, psychologically, the differences between the two senses are very great. Visual sensations form a manifold of three dimensions; sensations of tone, a manifold of two dimensions. Colour mixtures appear themselves as simple sensations, while mixtures of tones are analysable into their constituents. Again, there is no

such thing as tonal contrast, or a negative after-image of tone. The phenomenon of beats has been compared to that of flicker; but there is nothing in vision that resembles the combinational tones. And when we turn from description to explanation, we find that antagonism is the keynote of visual, and sympathetic resonance the keynote of auditory theory. — We may sum up these differences between sight and hearing, in a single word, by saying that the former is a chemical and the latter a mechanical sense.

Next after sight and hearing, in a list of the senses, stand taste and smell. These, too, seem to go together as a matter of course. Psychologically, indeed, they have good right to go together. Both alike are chemical senses, and the two groups of sensations are intimately connected in experience: so intimately, that in everyday life we are constantly attributing to taste what really belongs to smell. Most meats and vegetables are tasteless. If you hold your nose, you cannot distinguish apple from onion or raw potato, or vinegar from claret. A cold in the head does not affect taste, as we ordinarily suppose; what really happens is that the accumulation of mucus in the nose cuts off the sense of smell. It is clear that such gross confusion would not be possible unless the qualities of taste and smell were very much alike: nobody would confuse a colour with a tone! As a matter of fact, it may well be doubted if the scent of lavender and the taste of sugar do not stand, psychologically, nearer together than the taste of sugar and the taste of quinine.

On the biological side, also, the senses of taste and smell are closely related. Both of them, though in slightly different ways, stand guard over the great function of nutri-

tion, inviting the organism to what is wholesome and warning it of what is deleterious.

The sense of smell is of peculiar interest: partly on account of the problems which it sets to psychology, and which — as we shall see in the following sections — are still very far from solution; partly on account of the rôle that it has played in the course of organic evolution. Far back in the history of life, among the reptiles, the cortex appears as little more than an annex to the organ of smell. As development proceeded, the sense retained its importance as the servant of nutrition and reproduction: we know, for instance, how largely it bulks in the mental life of the carnivorous mammals. It is, however, essentially a land-sense: the mammals which live wholly or partially in the water — whale, dolphin, seal — possess a very rudimentary organ of smell, and are probably without smell sensations. The sense-organs in fishes which have been described as organs of smell differ in structure from the corresponding organs of land animals, and apparently furnish sensations, not of smell, but of something akin to taste. It is also a ground-sense: birds have, in general, very obtuse smell; and our own disregard of smell sensations is largely due to our assumption of the upright position.

On the other hand, there is no evidence for the statement, often as it is made, that in man the sense of smell is degenerating. Both in range of quality and in discrimination of intensity (§ 66), it holds its own as against the other senses. Moreover, odours still have a high biological importance as appetisers: the smell of cooking makes the mouth water, as we say; and invalids may be tempted to eat by the aroma of the dishes set before them. The significance of smell for nutrition is masked by the fact that, in man, stimulation of the organ from within the mouth, especially in the act of swallowing, is at least as important as its stimulation through the external nostrils; and here, as we have said, all the credit is taken by taste. Whether the sense of smell has any large share, primary or derivative, in the sexual life of man is a disputed point. There are, no doubt, large individual differences in this regard; but, on the whole, the evidence is decidedly in the affirmative.

§ 30. **The Olfactory Qualities.** — The sense of smell, like the senses of sight and hearing, includes a very large number of qualities of sensation. It is impossible to say, at present, what this number is; we know too little about the world of odours to be able to undertake its systematic exploration. Indeed, the number may always remain indeterminable, since new odours are constantly added to the list. The progress of chemistry and of the arts that depend upon it means the continual discovery of odorous substances; and every experiment upon the cultivation of flowers and fruits may, in favourable climatic conditions, furnish a new perfume.

Under these circumstances, we can do no more than give a provisional classification of the smell qualities, based on their introspective resemblances. The following division into nine classes dates, in the main, from the great Swedish naturalist Linnaeus.

1. *Ethereal or Fruit Odours.* — All fruit and wine odours; the scents of the various ethers; the smell of beeswax.
2. *Aromatic or Spice Odours.* — All spicy smells: camphor, turpentine, cloves, ginger, pepper, bay leaves, cinnamon, caraway, anise, peppermint, lavender, bitter almonds, rosemary, sassafras; thyme, geranium, bergamot; rosewood, cedarwood, etc.
3. *Fragrant or Flower Odours.* — All flower scents; vanilla, tonka bean, tea, hay; gum benzoin, etc.
4. *Ambrosiac or Musky Odours.* — Musk, ambergris, sandalwood, patchouli.
5. *Alliaceous or Leek Odours.* — Onion, garlic, asafoetida; india-rubber, dried fish, chlorine, iodine.
6. *Empyreumatic or Burned Odours.* — Roasted coffee, toast, tobacco smoke, tar, burned horn, carbolic acid, naphthalene, benzine, creosote.

7. *Hircine or Rank Odours.* — Stale cheese, sweat, valerian, root and stem of barberry and black currant, lactic acid, caproic acid.
8. *Virulent and Foul Odours.* — Opium, laudanum, French marigold, fresh coriander seeds, bed bugs, squash bugs.
9. *Nauseous Odours.* — Carrion flowers, stinkhorns, water from wilted flower stems, decaying animal matter, faeces.

All of these classes may be further subdivided, and in some cases the subdivisions may themselves be split up into still smaller groups. It is, however, unnecessary to go into more detail. The list is unsatisfactory, first, because there are many odours that cannot certainly be classed under any one of the nine headings; and, secondly, because the odours under certain headings (1 and 3, or 2 and 4) seem to be more nearly related than are particular odours under a single heading (2 or 6). Nevertheless, it serves to give an idea of the immense range and variety of the olfactory qualities.

Many of the stimuli mentioned in the list have sensory effects that extend far beyond the domain of smell. Thus the two ordinary anaesthetics, chloroform and ether, belong as scents to the ethereal group. But, further, inhaled chloroform tastes sweet, and inhaled ether bitter; while both stimuli may, by diffusion, give rise to sensations of cold and, by direct application, to sensations of pain. Pungent odours (ammonia, pepper, mustard) arouse pricking or tingling sensations in the nose and throat. The smell of onions and of horse-radish brings tears to the eyes; in some cases, the smell of hay or of newly turned garden mould has an unpleasant effect upon breathing. Odours of the eighth and ninth classes may excite the sensation of nausea. — In view of these facts, it becomes necessary for us to raise the question of the essential nature of the olfactory stimulus, and of its mode of action upon the organ of smell.

§ 31. **Olfactory Sensation and Olfactory Stimulus.** — Sensations of smell are aroused, not by the transmission of wave-motions through air or ether, but by the actual contact of material particles with the sense-organ. The odorous particles may be given off by volatile substances in our immediate surroundings, or may be brought from a distance by currents of air. They are received into the nose in the act of inspiration: if we wish to get the full fragrance of a flower, we sniff at it; so long as we hold the breath, we smell nothing. It follows that all smell stimuli must exist in the form of gas or vapour; solids and liquids are odorous only if they are also volatile.

Sensations of smell may also be set up by way of the posterior nares: especially is this the case, as we have said, in the act of swallowing. If scented air is inhaled through the mouth, and expired through the nose, the scent will be clearly perceived, though there is some loss of intensity due to the adhesion of odorous particles to the moist lining of mouth and throat.

It is possible, though it is by no means easy, to drive out all the air from the cavities of the nose, and thus to bring an odorous liquid into direct contact with the organ of smell. Experiments of this sort have been made, but with uncertain result. Even if we grant, however, that liquid stimuli can arouse sensations of smell, it would still remain true that the normal olfactory stimulus has the gaseous form.

There can be no doubt that the action of stimuli upon the organ of smell is chemical in its nature, so that a substance is odorous or inodorous by virtue of its chemical constitution. Many attempts have been made to express this fact in precise terms, — to discover precisely what sort of molecule is able to arouse an olfactory sensation. No single or general law has as yet been found. The following results show, however, that the prospect is not hopeless.

In the first place, it is agreed by most investigators that the chemical elements are inodorous. True, exceptions to the rule (chlorine, bromine, iodine) at once suggest themselves. It is probable, however, that these substances become odorous only in combination with the hydrogen of the air in the nasal cavities. If the rule holds, our field of search is so far restricted; we may neglect the atom, and turn our attention solely to the molecule.

Secondly, all odorous substances (with one exception) are derived from the trivalent, divalent, and univalent elements of the fifth, sixth, and seventh groups.[1] The single exception is given with the great group of the hydrocarbons. The real odorous substance in their case may, however, be a product of oxidation. Again, therefore, if the rule holds, our field of search is restricted; we may confine our attention to molecules which contain certain elements from group V., VI., or VII.

It must be confessed that these two rules, even if strictly valid, do not take us very far. Detailed study of the chemical composition of substances of like odour, and of the odour of substances of like chemical composition, does not, as yet, take us much farther. One point is worth mentioning: it has been found that the homologous series of organic chemistry furnish, within limits, series of related but progressively diverging odours, so that likeness or difference of smell runs roughly parallel to likeness or difference of chemical constitution. An illustration will make this rule clear. The series of fatty acids begins with formic (CH_2O_2), acetic ($C_2H_4O_2$), propionic ($C_3H_6O_2$), butyric ($C_4H_8O_2$), valerianic ($C_5H_{10}O_2$), caproic ($C_6H_{12}O_2$). All these substances have related

[1] A statement and explanation of the periodic law, and a table of the elements arranged in accordance with it, will be found in any good encyclopaedia. The important elements are: V. nitrogen, phosphorus, arsenic, antimony, bismuth; VI. oxygen, sulphur, selenium, tellurium; VII. fluorine, chlorine, bromine, iodine. Their serial positions should be noted.

odours, which become increasingly different with increasing distance between the terms of the series. Moreover, the odour, which in formic acid is weak, grows stronger and stronger as the series advances. Presently, however, the olfactory quality rather abruptly lapses: the higher acids — palmitic ($C_{16}H_{32}O_2$), margaric ($C_{17}H_{34}O_2$), stearic ($C_{18}H_{36}O_2$), etc. — are almost or entirely inodorous. — As things are, theory can do little with these and similar facts; but it is clear that, if such uniformities occur, a chemistry of smell must in the long run be possible of achievement.

In fine, then, we cannot correlate olfactory quality with the configuration of the molecule, as we can correlate visual quality with the wave-length of light, and auditory quality with the wave-number of sound, though we may hope that some day a chemical correlation will be made out.

§ 32. **The Dependence of Olfactory Sensation upon the Composition and Time-relations of Stimulus.** — Sight and smell are both chemical senses. We may, therefore, expect to find a certain resemblance in the mode of behaviour of their sense-organs. How far the resemblance goes, we shall discover only by experiment; but we may safely look to sight for guidance in our first investigations of smell. —

Two colours that are mixed in accordance with the first or second law of colour mixture either neutralise each other or produce a new, intermediate colour. What happens if we mix two odours?

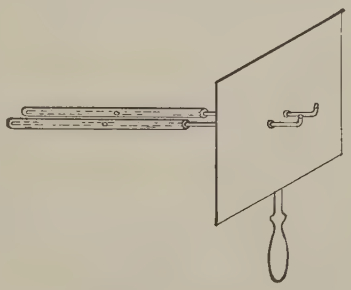

FIG. 18. Double Olfactometer (solid stimuli).

We may proceed in two ways: we may conduct the odours separately to the two nostrils, by means of the olfactometer; or — if chemical combination does not occur

— we may make a mechanical mixture of the odorous substances before smelling. In both cases, we obtain results analogous to those got by the mixture of colours.

First, there are undoubtedly odours which, if mixed in the right proportions, neutralise each other. Bridal bouquets often have gardenia mixed with their orange-blossoms, in order that the aromatic scent may weaken the too powerful fragrance. Tooth-powder of orris root is used to counteract the foetor ex ore. In medical practice, and in the operating room, recourse is had to this principle of compensation: balsam of Peru offsets the smell of iodoform, and carbolic acid the stench of pulmonary gangrene. Laboratory experiments yield the same result: the odour of red india-rubber, for instance, neutralises the odours of cedarwood, gum benzoin, paraffin, beeswax, tolu balsam, etc.

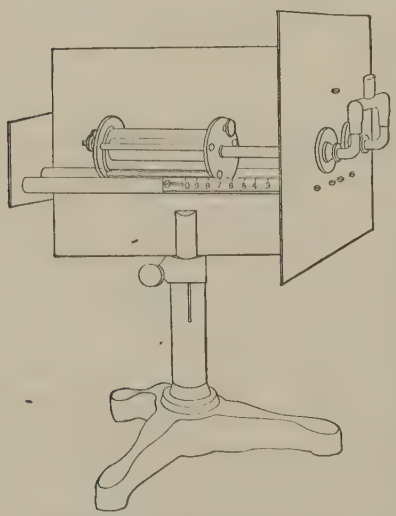

FIG. 19. Double Olfactometer (liquid stimuli).

Secondly, there are odours which, if mixed in the right proportions, give rise to a resultant odour, a new olfactory quality. Most of us have noticed that the addition of a few fragrant leaves to a bunch of flowers may alter the scent of the whole bouquet; that the mixture of two toilet perfumes may produce a perfume different from either; that the attempt to overpower a foul or nauseous odour by a perfume will sometimes set up a scent more

sickening than the first. Laboratory experiments bear out this conclusion: new odours arise, for example, from the mixture of musk and opium or listerine, iodine and ylang ylang or camphor, valerianic acid and lavender or hyacinth. In all such cases the resultant odour is simple and unanalysable; it resembles the component odours, but it cannot be resolved into them.

Whether odours have a constant mixing value, independent of their mode of origin, — whether, that is, we have in smell an analogue of the third law of colour mixture, — cannot be said with certainty. The trend of evidence appears to be towards the affirmative.

The likeness between these results and those of colour mixture is evident. Nevertheless, there are striking differences. Thus, smell mixtures are, in general, much less stable than colour mixtures. Experiment shows that two odours rarely neutralise each other completely for more than a few seconds; it is easy to obtain an unsaturated odour of the quality of the stronger component, but not easy to get actual extinction. This seems to mean that the chemical equilibrium of the olfactory cells is less stable than that of the retinal cones. In the same way, the new odour resulting from a twofold mixture is often transitory in character, giving place either to the odour of a single component or to an oscillation of the two. This is due, in many instances, to the fact that the sense-organ becomes more quickly adapted to the one stimulus than to the other, or that the substances mixed are not equally volatile; but in others it also seems to point to a chemical instability of the olfactory cells. Resultant odours of a more permanent kind may be secured by the mixture of a number of components. The flower perfumes of the perfume industry are, as a rule, quite complicated mixtures: heliotrope, for example, is derived from the mixture of vanilla, rose, orange-flower, ambergris and almond.

Again, it is impossible to draw a sharp line of division between

complementary odours and odours that combine. We should naturally expect that the members of the same or of related classes would mix, and that the members of diverse classes would cancel one another. Some ten years ago, a statement to this effect would have found support in the composition of toilet perfumes, in pharmaceutical practice, and in the results of psychological experiment. Recent work has proved, however, that no such rule can be laid down: odours of the second and eighth classes, for instance, may combine as readily as odours within either group, and odours taken from the same class may behave as complementaries. Evidently, there is in smell no such clean-cut principle of antagonism as we have found in sight.

The fact of adaptation to stimulus is, perhaps, more in evidence in the case of smell than it is even in that of vision. Odours of the most insistent kind fade out, if only the stimulation is kept up without intermission, in a comparatively short time. Workers in tanneries, cheese warehouses and fish markets, garbage collectors, habitual smokers, patients with iodoform dressings, medical students in the dissecting room, — these persons are, as a rule, quite unconscious of the odours that surround them. All of us have, probably, at one time or another, been asked to go into a certain room and "see if we don't smell fire," and have noticed that, after a few vigorous sniffs, we were wholly unable to say whether we did or did not. Laboratory experiments simply make these observations more precise. Thus, heliotrope becomes inodorous if smelled for about 5 min.; asafoetida in $1\frac{1}{2}$ min.; stale cheese in 8 min.; and so on.

Here, too, there are marked differences between smell and sight. The fading out of a given sensation does not mean the arousal of its complementary; there is no negative after-image of smell; adaptation to india-rubber does not leave us with a

scent of cedarwood or tolu or beeswax. The effect of adaptation is simply to increase our sensitivity for certain odours, and to reduce or destroy it for others. Thus, it has been found that a partial adaptation to cedarwood or tolu or beeswax renders the nose more sensitive to the smell of india-rubber, while partial adaptation to glycerine soap or cocoa butter or Russian leather has no such effect. On the other hand, adaptation to iodine leaves us insensitive to the odour of eau de Cologne, absolute alcohol, heliotrope, oil of caraway. In this way, a continuous adaptation of the sort mentioned above may materially change the world of odours: the user of perfumery, the smoker, the hospital attendant, will be peculiarly susceptible to certain scents and peculiarly obtuse to others. There is, of course, a possibility that the sense of smell as a whole may be blunted by the repeated application of the same stimulus.[1]

§ 33. **Theory of Smell.** — The organ of smell[2] is extremely simple. It consists of a patch of brownish mucous membrane, not much larger than one's little-finger nail, which lines the roof and part of the walls of the extreme upper portion of the nasal cavities. This terminal pouch is so narrow and so remote that the air current of respiration does not reach it; the olfactory epithelium can be stimulated only by diffusion or by eddies from the main stream. The olfactory cells are set amongst columnar supporting cells; they are very slender, possess a large nucleus, and are prolonged peripherally as rod-shaped processes ending between the columnar cells at the free surface of the epithelium.

[1] It is said, in recent text-books, that smokers possess only about $\frac{2}{5}$ of the normal sensitivity to odours. The statement is apparently taken from H. Griesbach, who in 1899 published a comparative study of the senses of hearing, smell and touch in the blind and the seeing (*Archiv f. d. gesammte Physiologie*, lxxiv., 577; lxxv., 365, 523). But Griesbach worked only with india-rubber!

[2] The author uses the Deyrolle model, *Coupe médiane du nez grossi.*

This simplicity of structure suggests at once that the organ of smell must respond to olfactory stimulus in the same sort of way as the eye to light, and not as the ear to sound. For every sensation of tone we find a separate structure in the cochlea. On the other hand, all the sensations represented in the colour pyramid are derived from the six antagonistic processes in the cones (*Bk-W*, *B-Y*, *R-G*) and from the cortical grey. Our daylight vision, rich as it is in sense qualities, depends simply upon four chemical reactions, three reversible and one constant. Now a theory which, like the theory of vision, reduces the manifold of psychological elements to a small number of elementary psychophysical processes is termed a theory of components. Black, white, grey, and the invariable *R*, *G*, *B* and *Y* are the components of our visual theory: psychophysically, they are the elements of vision, though psychologically they are no more elementary than orange or violet or purple. It is important to bear this distinction in mind.

We may expect, then, that the right theory of smell will be a component theory. This expectation is borne out by the fact, already mentioned in § 32, that adaptation to a particular odour leaves us insensitive to some, while it does not impair our sensitivity to other odours. The odours that are killed by adaptation to iodine, for instance, evidently require for their arousal the same psychophysical processes: they stand to iodine in much the same relation that rose, lilac, mauve, heliotrope, purple bear to violet. If, therefore, we could work over the whole range of olfactory qualities, and find out which are weakened or blotted out, and which are left intact, by adaptation to the various odours taken singly, we might hope to discover

the psychophysical elements of olfactory sensation. Indeed, the programme need not be made so comprehensive: if we could work systematically with even a few odours, selected from all the nine classes and their recognised subdivisions, it is probable that the outlines of a component theory would emerge from our results.

The work is, however, exceedingly laborious, and consumes a great deal of time. Something has been done; very much more remains to do. It has been calculated, on the basis of our present knowledge, that 30 or 40 specific chemical processes must be assumed for the sense of smell, — many more than for daylight vision. It is unlikely that there are 30 or 40 kinds of olfactory cells. But whether there are, say, 10 sorts of cells, each the seat of 3 or 4 processes, or 3 or 4 sorts of cells, each the seat of 10 different chemical processes, we have no possible means of deciding.

While these phenomena of adaptation afford the strongest support to a component theory, they do not by any means stand alone. It is clear that the results of smell mixture — resultant odours and compensations — point in the same direction, as does also the mere fact that odours may be grouped, by their introspective resemblances, into a number of distinct classes. Further evidence comes from pathology. In cases of partial anosmia, which occurs both as congenital defect and as the consequence of influenza, diphtheria, etc., the patient is insensitive to some and sensitive to other odours: thus, the musky odours or the vanilla-group of the fragrant odours may be destroyed or weakened, while all the rest persist in their normal character. Cases of parosmia, or subjective perversion of the sense of smell, fall into similar groups, which, so far as they have been investigated, appear to correspond with the fourth, fifth, sixth and ninth olfactory classes.

References for Further Reading

§§ 29–33. *Die Physiologie des Geruchs*, 1895, by H. Zwaardemaker, professor of physiology at Utrecht: J. Passy, *Revue générale sur les sensations olfactives*, in *Année psychologique*, ii., 1806, 363 ff.: W. Wundt, *Physiologische Psychologie*, ii., 1902, 46 ff.: W. Nagel, *Der Geruchssinn*, in *Nagel's Handbuch*, iii., 1905, 589 ff.

TASTE

§ 34. **The Gustatory Qualities.** — For the most part, sensations of taste come to us blended with sensations of smell, touch and temperature. These blends have a curiously unitary character: it is only by directing the attention, in the light of past experience, first to one and then to another aspect of the given whole, that we can distinguish the separate components. Thus the flavour of a peach, or of black coffee, seems to be simple and unique; but we may happen to notice the aroma before we begin to taste, and in this way take an involuntary first step towards analysis. At times, the difference between smell and taste comes to us with a sort of shock; the bitter taste of unsweetened chocolate, for instance, is in sharp contrast to the aromatic odour. Again, we may remark that our food to-day is more savoury than it was yesterday, when our nose was stopped up with a cold; or we may discover that the repulsive flavour of certain medicines, such as castor oil, is avoided by the simple expedient of holding the nose. In all these cases, and in many others like them, everyday experience plays into the hands of psychological analysis. Smell and taste are, after all, separate senses with separate sense-organs; and while a blending of their sensations is the rule, occasions are bound to arise when we taste without smelling or smell without tasting.

There is no such natural separation of taste from touch and temperature. It is, however, not difficult to observe that in oily and fatty tastes we have something that is precisely like the feel of greasy fingers, and in pungent and biting tastes something that is precisely like the pricking of pungent odours in the nose or the bite of mustard-plaster upon the skin. The cold of ice-cream in the mouth is the same as the cold of icy water to the hands; and when a too hot soup scalds the tongue we have — apart from the impairment of taste itself — the same sensations as when we step into a too hot bath. Having made these observations, we are able to single out, by the attention, the touch and temperature components in ordinary tastes.

If the taste-blends are thus analysed, and the foreign constituents referred to the sense-departments to which they properly belong, there remain only four qualities of taste: sweet, bitter, sour and salt. Here is poverty indeed, as compared with the wealth of sight, hearing and smell! — and a poverty all the more striking, since taste makes so brave a show of variety in everyday life.

This result depends, not only upon introspective analysis of the taste-blends, but also upon a systematic exploration of the organ of taste with very various kinds of stimulus. Before the experimental tests were made, the lists of gustatory qualities put forward by different authors were, as we should expect, widely different. It would, however, be a mistake to suppose that they have grown steadily shorter as analysis has advanced. None of them are very long. Smell, indeed, seems to have been practically eliminated almost from the outset, though some physiologists speak of aromatic tastes, foul tastes, etc., and it is odd that the rule of holding the nose during experiments on taste was laid down for the first time by the French chemist M. E. Chevreul as late as 1824. On the other hand, the touch and temperature components evidently

presented great difficulty. We find oily tastes, pungent tastes, smooth tastes, astringent tastes, etc., figuring in the scheme of taste qualities; and contrariwise we find sour and salt transferred, on account of their astringent and burning character, from the sense of taste to that of touch. Here, then, are give and take, addition and subtraction: Linnaeus brought the number of tastes up to 10, but a recent investigator[1] who reduces them to 2 (sweet and bitter) is merely repeating what had been said sixty years earlier.[2]

It was long supposed that nausea is a taste quality; this view was taken, for instance, by so great a man as Johannes Müller, the father of modern physiology, on the ground that the sensation aroused by pressure on the base of the tongue — putting your finger down your throat — cannot be identified with any quality of touch.[3] At the present time, many psychologists incline to the view that the alkaline and the metallic tastes must be regarded as elementary qualities of taste; but tests made with the nose closed prove that the irreducible factor in both cases is due to smell. —

If smell is ruled out, the ordinary taste-blends may be analysed as follows. Sour is at first astringent; then, as it becomes stronger, burning; finally, purely painful. Salt is attended by a weak burning, which does not rise to positive pain. Sweet brings with it the perception of smoothness and softness; at high intensities of stimulus, it pricks or gives a sharp burn. Bitter suggests something fatty; at high intensities it may burn.

§ 35. **Gustatory Sensation and Gustatory Stimulus.** — In order to be sapid, a substance must be, to some extent, soluble in the saliva of the mouth. If this condition is fulfilled, it may exist in any form, as solid or liquid, vapour or gas.

There are, however, soluble substances which are taste-

[1] W. Sternberg, *Geschmack und Chemismus*, in *Zeitschrift f. Psychologie u. Physiologie d. Sinnesorgane*, xx., 1899, 387.

[2] By L. H. Zenneck in J. A. Buchner's *Repertorium f. d. Pharmacie*, lxv. (2te Reihe, xv.), 1839, 224 ff.

[3] *Handbuch der Physiologie des Menschen*, ii., 1840, 489.

less. We are thus thrown back, as in the case of smell, upon the question of chemical constitution, and must try to work out a correlation between stimulus and sensation in chemical terms. Now chemistry uses the terms salt, acid, sugar as class-names for related groups of compounds. All three words — as well as the phrase 'bitter principles,' which is employed in pharmacy and in organic chemistry — are borrowed from the sense of taste; and we can say off-hand, from ordinary experience, that acids generally taste sour, salts salty, and sugars sweet. A little enquiry brings out the further fact that the bitters with which we are most familiar are alkaloids. Can we, then, correlate the four taste qualities with these four types of chemical combination?

Unfortunately, the rule has puzzling exceptions even in the cases of sour and salt. It is true that we get the taste of salt only from chemical salts: but there are chemical salts that taste sweet, others that taste bitter, and others again that have no taste at all. It is also true, apparently, that we get the taste of sour only from chemical acids, or from substances that contain acids: but there are acids that taste sweet, acids that are tasteless, and at least one acid (hydrocyanic) which is said to taste bitter. The suggestion has been made that the sour taste of the majority of acids may be accounted for by their ionisation in aqueous solution, — may be ascribed, that is, to the setting free of the common ion hydrogen. Hydrocyanic acid is only partially ionised, and the tasteless fatty acids like palmitic, stearic and oleic are insoluble in water. — There is undoubtedly a close chemical relation between sweet and bitter; a very slight change of chemical constitution will change the one taste into the other. The groups of sweet-tasting and

bitter-tasting substances are, however, extremely heterogeneous.

In fine, then, much detailed work is needed, in taste as in smell, before any general law of the correlation of stimulus and sensation can be made out.

It has been pointed out that the inorganic sweet-tasting substances are derived from elements of the III., IV. and V. groups, and that these elements are, so to say, double-faced, since they combine with acids as bases and with bases as acids to form salts. On the other hand, the inorganic bitter-tasting substances are derived from electropositive elements of the I. and II., and from electronegative elements of the VI. and VII. groups. Here is the hint of a principle, which may perhaps be carried over to the organic compounds; and it has, in fact, been maintained that all the sweet-tasting organic substances have this double, ±-character, while all the bitter-tasting — though closely related to them — have either the *plus* or the *minus* sign. If the rule holds, we can readily understand that a slight change of the sweet-generating molecule will transform it into a generator of bitter. However, it is best to be on one's guard against premature generalisation.

§ 36. **Mixtures and Adaptations.** — We know, from every-day experience, that certain tastes are more or less antagonistic. Sugar moderates the bitter taste of coffee and chocolate, and the sour taste of unripe fruit. Sour and salt offset each other, to a certain extent, in sour pickles and salad dressings. Salt corrects the too luscious sweetness of an overripe melon. On the other hand, bitter and salt may exist side by side, as in the taste of olives; and bitter and sour, as in that of a green peach.

Observations of this sort are, however, unsatisfactory. First of all, the act of eating or drinking brings the taste-stimulus into contact with the whole surface of the tongue. If, then, the particular stimulus contains salt and bitter,

we may have the sensation of salt set up at a part of the tongue which is especially sensitive to salt, and the sensation of bitter at another part, especially sensitive to bitter: the two qualities will thus appear side by side, just as a blue and a yellow may appear side by side in the field of vision. To obtain assured results we must apply the mixed stimulus at one and the same point. Secondly, the four taste-qualities require different times for their arousal: salt comes first, then sweet, then sour, and bitter last. It is quite possible that, in ordinary life, these time-differences escape notice, so that we may regard two tastes as occurring together when really they occur in succession. And thirdly there is no guarantee, under the conditions, that stimuli are mixed in the right proportions. For all these reasons, we must have recourse to experiment.

A careful study of taste-mixtures in the laboratory brings out the following facts. With high intensities of stimulus, the two tastes seem not to influence each other; they simply oscillate. With low intensities, there is in most cases a partial compensation, which is least for sweet and sour, better for salt and bitter, better still for sour and bitter, sour and salt, and sweet and bitter. The antagonism is not so clean-cut as it is in the case of sight; we rarely, if ever, obtain actual neutralisation of two compensatory tastes. Only in one instance, the mixture of sweet and salt, is there any reminder of the second law of colour mixture. If salt is added, little by little, to a weak sweet, there presently emerges a taste which is neither salt nor sweet, but flat and vapid.

We remarked in § 34 upon the curiously unitary character of the taste-blends. It is worth noticing here that the unitariness persists in spite of the antagonistic nature of the taste qualities.

Think, for instance, of the flavour of a ripe peach. The ethereal odour may be ruled out by holding the nose. The taste components — sweet, bitter, sour — may be identified by special direction of the attention upon them. The touch components — the softness and stringiness of the pulp, the puckery feel of the sour — may be singled out in the same way. Nevertheless, all these factors blend together so intimately that it is hard to give up one's belief in a peculiar and unanalysable peach-flavour. Indeed, some psychologists assert that this resultant flavour exists; that in all such cases the concurrence of the taste qualities gives rise to a new, basic or fundamental taste, which serves so to say as background to the separate components. There is, however, no need to make any such assumption. It is an universal rule in psychology that, when sense-qualities combine to form what is called a perception, the result of their combination is not a sum but a system, not a patchwork but a pattern. The parts of a locomotive form a system; the colours of a carpet form a pattern: in neither case is there a mere heaping together of materials. The same thing holds of perception. Hence, just as it would be absurd to say that the plan of the locomotive is a new bit of steel, or the pattern of the carpet a new bit of coloured stuff, so is it wrong to say that the peach-character of a certain taste-blend is a new taste quality. This character shows us the pattern of the blend, the specific way in which the components are arranged; it is not itself a sensation. — We shall return to the general question later, in Pt. ii.

It was pointed out in § 29 that there is an intrinsic likeness between the sensations of taste and of smell. This fact is clearly recognised in pharmacy. Thus, we are advised to take castor oil or cod-liver oil in claret or lemonade; the sour taste corrects the nauseating or hircine odour. Quinine, which tastes bitter and has no smell, is corrected by essence of orange peel, which has an aromatic smell and no taste. In all sorts of children's medicines, a disagreeable odour is offset by a sweet taste, or a disagreeable taste by some pleasant odour. The result obtained is, of course, only partly due to the cancellation of sensations. When a child has fallen down and hurt itself, we try to turn its attention to

something else: we tell it a fairy story, or give it a lump of sugar, and the crying stops. The same principle, of distraction of attention from the unpleasant to the pleasant, plays its part in these medicinal mixtures. On the other hand, adults are less suggestible than children, and the corrections hold for us as for them; while an attempt to offset the stench of castor oil, say, by a popular melody or a comic picture would strike us as laughable. Undoubtedly, then, sensations of taste and smell are sufficiently alike to exert a direct influence upon one another. This conclusion loses much of its strangeness if we remember that, phylogenetically, taste and smell are simply two departments of a single chemical sense, the one differentiated for the reception of liquid, and the other for that of gaseous stimuli.

Adaptation to tastes is less obvious than adaptation to odours. It seems that the organ of taste is more resistant, chemically more stable, than the organ of smell. Apart from this, however, our attention, in eating and drinking, is largely taken up with the smell and touch components of the taste blends. Besides, we usually have at hand the materials (salt, sugar, vinegar, etc.) for raising the intensity of taste stimuli; we reach instinctively for the salt-cellar or the vinegar cruet as soon as we miss the taste of salt or sour. Nevertheless, there are times when the fact of adaptation stands out clearly enough. An orange that would taste sweet at the beginning of a meal tastes unpleasantly sour if we take it after a sweet pudding. A stock soup that is at first disagreeably salt gets better after the first few spoonfuls. If we have the courage to attack a plate of early strawberries without sugar, we soon grow accustomed to the acid. — These observations are confirmed by the results of experiment.

In smell, the effect of adaptation is to increase our sensitivity for certain qualities, and to reduce or destroy

it for others. In taste, where there are but four qualities, the negative result of adaptation is generally confined to the quality of the stimulus itself: adaptation to bitter weakens or abolishes the taste of bitter, but leaves the rest at least as strong as they were before. There are, however, exceptions to this rule. If the tongue is painted with a fitting solution of cocaine hydrochlorate, we lose first the quality of bitter, and then that of sweet; if it is painted with gymnemic acid, we lose first the quality of sweet and then that of bitter; in both cases, salt and sour persist. The action of these substances upon the end-organs has not been explained. — The positive results of adaptation must be stated with some reserve, since there are great individual differences among observers. It seems, however, that adaptation to any one of the three tastes sour, sweet, salt affects the remaining two: a foregone sour, for instance, enhances a present sweet or a present salt, and so on.

The sense of taste appears, further, to show phenomena of contrast, more or less akin to those of vision. A sour applied to the one side of the tongue brings out, for certain persons, the taste of a subliminal sweet applied to the other side. Contrasts may also be obtained, in laboratory practice, between salt and sour, and salt and sweet. On the other hand, subliminal bitter, applied at the same time as sweet, sour or salt, is usually sensed, if at all, as sweet; and supraliminal bitter is, from the first, strong and insistent.

Nothing is definitely known about after-images of taste. Many sweet stimuli leave a bitter taste in the mouth; but this may be due to the chemical relationship of the sweet-tasting and the bitter-tasting substances of which we spoke in § 35. It is note-

worthy that, to many persons, distilled water, an intrinsically tasteless stimulus, tastes distinctly bitter; to others it may taste sour or sweet. Various explanations have been suggested. The taste may be simply an after-effect of adaptation: the mouth is never entirely free from particles of food. Or it may possibly result from the merely mechanical stimulation of the end-organs, just as a flash of light results from mechanical pressure on the eyeball. Or, again, it may be an associative process, an idea or, as it were, an illusion of taste. This and many similar points in the psychology of taste still await explanation.

§ 37. **Theory of Taste.** — The description given of the olfactory cells holds also for the specialised sensory cells which form the end-organs of taste: they are long, slender rod-cells, with large nucleus, set among supporting cells of the same sort as the columnar cells of the olfactory mucous membrane. The rod-cells are not, however, irregularly distributed between the supporting cells; they are gathered together into flask-shaped structures, which are known as the taste-buds or taste-bulbs. At the centre of the bulb stands a group of rod-cells, intermixed with a few supporting cells; the rod-processes converge peripherally to the pore of the bulb. Next comes a wrapping of supporting or cover cells; while the outer wall of the bulb is composed of epithelial cells of special form.

The taste-bulbs occur in greatest numbers in the trenches surrounding the circumvallate papillae at the root of the tongue.[1] They occur also along the edges of the tongue, posteriorly in the folds of the regio foliata and anteriorly in the fungiform papillae; and at the tip again in the

[1] The author uses the Deyrolle model, *La langue vue du côté droit.* He knows of no models that show the sense-organs of nose and tongue in enlarged vertical section. The models must therefore be supplemented by charts (*e.g.*, those of Wenzel's *Anatomischer Handatlas*) or lantern slides.

fungiform papillae, the bright red specks which can be seen standing out from the dull pink of their surroundings. The central area of the surface of the tongue is insensitive to taste. In general, the root of the tongue is especially sensitive to bitter, the tip to sweet, and the middle section of the edges to sour.

The distribution of the end-organs of taste in man shows great individual differences. In adult life, functional taste-bulbs are found on the surface of the tongue, with the exception of a central area of varying size, and on the soft palate ; less constantly on the arches and veil of the palate and on the uvula ; rarely on a portion of the hard palate. They also occur, curiously enough, in the interior of the larynx and on the epiglottis, regions that are not normally stimulated by sapid substances. Their presence here, and on the superior (posterior) surface of the veil of the palate, accounts however for the sweet taste of inhaled chloroform and the bitter of inhaled ether (§ 30). In children, the taste-bulbs extend over the whole surface of the tongue, and are also found in the mucous membrane of the cheeks, — facts that explain, perhaps, the childish tendency to take big mouthfuls.

Why the central area of the tongue should lose its sensitivity, in adult life, is not easy to say. It is clear, however, if we consider the mechanics of chewing and swallowing, that there must be a stagnation of sapid liquid at the back and on the edges of the tongue ; and it is clear that this stagnation is assisted by the trenches about the circumvallate papillae and by the folds of the regio foliata. These, then, are the important regions for tasting. They are more important even than the tip of the tongue, which merely samples the substances that enter the mouth ; and we find, as a matter of fact, that insensitivity of the tip not infrequently coexists with normal sensitivity of root and sides.

The reduction of the organ has analogies in other departments of sense. In hearing, for instance, the range of sensation is diminished ; the highest audible tone is more than an octave higher in childhood than in old age. We may suppose that the shortest

fibres of the basilar membrane gradually lose their elasticity. In smell, again, the acuity of sensation is diminished; children are much more sensitive to odours than adults, though they do not appear to have a wider range of qualities. It is possible that, in the course of years, the olfactory mucous membrane is coated with minute particles of dust, etc., so that the cells are less easily stimulated.

The papillae of the same region do not all react in the same way to gustatory stimuli. Thus, of 39 fungiform papillae, stimulated with salt, sugar, hydrochloric acid and quinine, 4 proved to be wholly insensitive, while 31 were sensitive to sweet, 31 to salt, 29 to sour, and 21 to bitter; one was sensitive only to sweet, and one only to bitter. It seems probable, then, that there are four kinds of taste-bulbs, each one sensitive to a single quality of taste; and that all of these, or three, or two, or only one, may be present in a given papilla.

This hypothesis agrees with the observed facts of taste mixture and of adaptation, and is also borne out by the pathological cases of loss of taste; the ageusia may be complete, or may affect some qualities more than others. On the other hand, it is impossible to say whether the distinction of the four classes of taste-bulbs is absolute. There are no anatomical differences that might help us to a decision. We must suppose that the substance of the taste cells has been chemically differentiated, for the reception of the different forms of stimulus; but we cannot say whether the specialisation of function has been carried to the same point in all taste-bulbs.

It has been suggested that the extreme sourness of the orange eaten after sweet pudding is due to a contrast of feelings; the sour after the sweet is more unpleasant than a sour standing alone. Even, however, if we grant — and the point is more than doubtful — that contrast between feelings occurs, introspection shows that the sour quality is itself intensified; and the explanation is there-

fore to be sought in the sphere of sensation. The sweet-sensitive bulbs have been put out of function by adaptation to the sweet of the pudding, so that the mixed, sweet-sour stimulus affects only the sour-sensitive bulbs. Hence the orange naturally tastes sourer than it does under ordinary circumstances, when the sweet and sour components are able in some measure to offset each other.

It is more difficult to account for the fact that a sour, etc. applied to the one side of the tongue brings out the taste of a subliminal sweet, etc. applied to the other side. We may, of course, challenge the fact itself. Liquids are apt to run on the surface of the tongue, and it is conceivable that the stimuli used in the experiments spread across the middle line. We know, however, that the terminal radiations of the n. lingualis which supply the one half of the tongue extend across the middle to the opposite half. The two groups of taste-bulbs, though locally distinct, are thus brought into connection at the periphery by their common nerve supply. —

Nothing definite is known of the order of development of the taste qualities. A good deal has been made of the fact that sweets cloy and bitters whet the appetite, while salts provoke and sours quench thirst. This, however, is no argument for an original fourfold differentiation of the sense of taste : appetite is governed largely by smell. Some authors regard salt as a quality of late development, on the ground that the word refers to a particular substance, while sweet, bitter and sour are general terms, and that children and uneducated persons often confuse salt with sour. But we find that many primitive languages have no distinctive word for bitter ; that some languages use the same word for sweet and salt ; and that uneducated persons may also confuse bitter and sour ! We have also seen that sour and salt have similar effects upon the organs of touch (§ 34). In view of the unitariness of the taste-blends, it is not surprising, then, that the two qualities should be confused by persons unskilled in introspection.

References for Further Reading

§§ 34–37. W. Wundt, *Physiologische Psychologie*, ii., 1902, 52 ff.; C. S. Myers, *Taste*, in *Reports of the Cambridge Anthropological Expedition to Torres Straits*, II., ii., 1903, 186 ff.; *The Taste-names of Primitive Peoples*, in *British Journal of Psychology*, i., 1904, 117; H. Zwaardemaker, *Geschmack*, in K. Asher and L. Spiro, *Ergebnisse der Physiologie*, II., ii., 1903, 699; W. Nagel, *Der Geschmackssinn*, in Nagel's *Handbuch*, iii., 1905, 621 ff.

CUTANEOUS SENSES

§ 38. **The Skin and its Senses.** — In popular parlance, touch is ranked as a fifth sense beside sight and hearing, taste and smell, and the organ of touch is the skin. Neither the sense nor its organ is very strictly defined. We may say, however, that the word skin denotes the whole membranous investment of the body; it includes not only the skin proper, but also the red area of the lips, the lining of the cavities of mouth and nose, the conjunctiva and cornea of the eye. In so far as this surface is not occupied by organs of special sense, such as taste and smell, it represents the organ of touch. Hence the name touch applies to all the sensations aroused by contact of the bodily surface with objects of the material world. A thing is hard, soft, warm, cold, painful to the touch; it is by touch that we distinguish wet and dry, light and heavy, rough and smooth, yielding and resistant, sharp and blunt, clammy and greasy, motionless and moving.[1] Exception is made, again, only of those properties, such as odour and sapidity, that appeal to special senses. And here, naturally, there is no attempt at analysis; the sting of pungent odours and the bite of pungent tastes — qualities that really belong to touch — are referred to smell and taste themselves.

[1] It is, of course, as plain to common sense as it is to psychological observation that these distinctions are often drawn in terms of sight; we see that a thing is wet or heavy or in motion. What is now under discussion, however, is the feel of objects that are actually in contact with the skin.

Our experience with timbre and with the blends of smell and taste puts us on our guard in the present instance; we shall not, without question, accept wet and dry, rough and smooth, etc. as ultimate qualities of tactual sensation. Instead, however, of working through the list in detail, we may at once clear up a confusion that inheres in the popular notion of touch, — the confusion between sensations from the skin and sensations from the tissues that lie beneath the skin. Pick up a pen from the table, or give a swing to your revolving bookcase, or try to open a window that has swelled with the rain: in every case you will find that the sensations from the skin are blended with internal sensations. Popularly, the whole complex is attributed to the sense of touch; psychologically, the two sets of sensations are different and must be referred to separate senses.

Suppose, however, that the subcutaneous senses are ruled out: the question still remains whether the skin itself is the seat of one or of more than one sense. And introspection favours the second alternative. There is no resemblance, for example, between the hard smoothness and the chill of a bit of ice, or between the rough brittleness and the warmth of new-made toast; we may safely mark off the sense of touch from the sense of temperature. Nor is there, when we reflect upon it, any resemblance between touch and pain. Indeed, the two kinds of sensation are distinct in time as well as in quality: if we dip the hand into very hot water, or take up a very hot plate, we sense the contact appreciably earlier than the pain. It would seem, then, that the sense of touch must also be marked off from the sense of pain.

To go beyond this point, we must have recourse to experiment. The surface of the skin must be explored,

accurately and minutely, with all sorts of stimuli, — mechanical, thermal, electrical, chemical, — and the sensations which it yields must be described and classified. Much work of this sort has been done, and the psychology of the skin, though still unsettled in sundry details, has thus been put upon a firm basis. —

It is found, first, that the surface of the skin is not uniformly sensitive. Sensations can be obtained only from definite spots or points; the remaining area is insensitive. The spots are fixed in their position, so that they always respond in the same way to the same stimulus; they undoubtedly indicate the presence, in the substance of the skin, of separate sense-organs. It is found, secondly, that these spots are of four distinct kinds: they furnish the sensations of pressure, of warmth, of cold, and of prick. In other words, there are four cutaneous senses, — those of pressure, or of touch in the narrowest sense, of warmth, of cold, and of pain. We will take them in order.

What is ordinarily called the sense of touch thus turns out to be highly composite, — a mixture of the sensations derived from four cutaneous and from a number of subcutaneous senses. It follows, of course, that the terms used in current speech to denote qualities of touch are not directly available for psychology. We have words like pressure, contact, prick, sting, soreness, smart, ache, and we must somehow make them serve our scientific purpose. But the selection is not easy, and the same term may, as a matter of fact, mean different things in different books. Hence it is important that the descriptions given in these Sections be verified by actual test: the instruments required are exceedingly simple, and their manipulation is straightforward. The particular name will then stand for a special bit of elementary experience, a particular feel; the analyses of cutaneous complexes will be analyses of concrete sense-material, and not a mere play of words; and, on

the other side, it will be possible by introspective reference to follow the accounts given by authors who employ a different terminology.

§ 39. **The Pressure Sense.** — If with the point of a pencil you brush one of the hairs that are sparsely scattered over the back of the hand, you obtain a weak sensation, of bright quality, which is somewhat ticklish, and which though thin and wiry yet has a definite body. This sensation, which we may term the sensation of contact, is physiologically a weak sensation of pressure. Wherever the skin carries hair, — that is, over about 95 per cent. of the cutaneous surface, — the hair-bulb is the organ of the pressure sense.

Pressure sensations may be studied systematically by means of the horse-hair point shown in Fig. 20. If you look at a hair on the back of the hand, you will notice that the shaft runs obliquely into the skin. Just to windward of the hair, directly over the bulb, lies a pressure spot, which is easily found by a few trials with the horse-hair point. By applying the horse-hair to the pressure spot, with different degrees of pressure, it is possible to call out the pressure sensations at different degrees of intensity. You get, first of all, the wiry, bright sensation of the former experiment. As the pressure is increased, the sensation too becomes heavier, more solid: at times it has about it something springy, tremulous, elastic; at

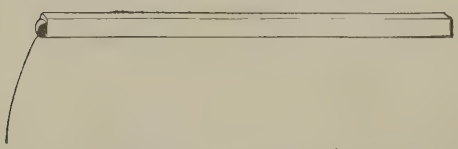

FIG. 20. Horse-hair point, for exploration of the cutaneous surface. A piece of horse-hair, about 2 cm. in length, is attached by sealing-wax to the end of a match.

times it appears simply as a little cylinder of compact pressure. Finally, at still higher intensities, the sensation becomes granular: it is as if you were pressing upon a small hard seed embedded in the substance of the skin. The granular sensation is often tinged with a faint ache, due to the admixture of a pain sensation; and is sometimes attended by a dull, diffuse sensation derived from the subcutaneous tissues. It may, however, appear as pure pressure sensation.

If the hairless regions of the skin are explored with the horse-hair point, pressure spots will be discovered which yield the same sensations as the hair-bulbs. The organs of pressure are here to be found in very similar structures, known as the corpuscles of Meissner.

The end-organs of pressure may be stimulated by pressure from without, by traction or pull, and by the wrinkling or stretching of the skin itself. They respond, that is, to any decided change of the local level of pressure, whether the change is positive or negative, rise or fall. They do not, all alike, furnish the graded series of sensations which we have just described, but are, so to say, tuned to different intensities of stimulus, so that a pressure which evokes the granular sensation at one spot may call out only the weak, bright sensation from another. There is, however, no further difference in the nature of their response; all the sensations of pressure belong to this single series.

Pressure spots are found over practically the whole extent of the skin. Their distribution differs in different regions. On the average, there are about 25 of them to the square centimetre; but this number may drop, for instance, to 7 on the upper arm, and may rise to 300 on the scalp.

Adaptation of the pressure sense is a matter of everyday experience. So long as we sit still, we are hardly aware of the pressure of our clothes; and the man who is

looking for the spectacles that he carries on his forehead has become a stock figure in the comic papers. The positive after-images of pressure ordinarily escape notice, since attention turns rather to the object arousing the sensation than to the sensation itself. They may, however, be intensive and of long duration; the deformation of the skin persists awhile, after the removal of the stimulus, and this after-affect of stimulus shows itself in a continuance of sensation.

It seems, at first, hardly credible that the end-organs of pressure should not be differentiated for the reception of different kinds of stimuli. When we think of the great variety of our tactual experience, and when we remember further that the same stimulus has markedly different effects if applied to different parts of the skin, we are almost forced to believe in a number of qualitatively distinct sensations. Nevertheless, the verdict of experiment is decisive here, as it was decisive in the somewhat similar case of taste. And we must not forget the facts on the other side. First, the stimuli that normally affect the skin are areal stimuli, appealing to a group of diversely tuned pressure organs; and the texture of the skin itself, and the nature of the underlying tissues, vary from place to place. There is, then, every chance in ordinary experience for typical differences in the intensity and the temporal course of pressure sensations. Now the sensations which we have termed contact, pressure, and granular pressure, although they are evoked by different intensities of the same stimulus and are on that account usually considered as different intensities of the same quality, are at least as distinct as red and pink, or yellow and orange; and if we may not call them psychological qualities, we must at least say that they do the same service for touch that true qualitative differentiation does for other senses. Secondly, the greater number of normal stimuli affect other organs, cutaneous or subcutaneous, besides those of pressure. Hence most of our tactual experience does, in strictness, consist of more than one quality, because it derives from more than one sense. Thirdly, as has been said above, the atten-

tion is generally concerned rather with the stimulating object than with the sensation which it excites. Here touch borrows from sight in much the same way as taste borrows from smell; visual characters of form, size, texture, etc., are so firmly associated to the feel of the stimulus that the skin gets the credit of a good deal of work done by the eye.

We shall have occasion, in § 50, to analyse some of the commoner tactual complexes. In the meanwhile, this general statement of the various factors which enter into them may lessen the strangeness of the experimental results.

§ 40. **The Temperature Senses.** — If you draw the rounded point of a lead pencil slowly and lightly across the back of the hand, or, better, across the surface of the closed eyelids, you will get, here and there, definite flashes of cold. There is a continuous sensation of pressure, due to the direct or indirect stimulation of pressure spots by deformation of the skin; but this continuum is dotted by sensations from the cold spots.

For systematic work, it is best to use a hollow point of metal, which can be kept at a constant temperature by the passage of a stream of water. The average natural temperature of the healthy skin may be put at about 33° C.[1] With the metal point held at 12°–15° C., one obtains the characteristic sensation from the cold spots, and with the point at 37°–40° C., the sensation from the warm spots. Both are larger, more extended than the sensation of pressure. The cold seems to lance down from above; it is set up at once in its full in-

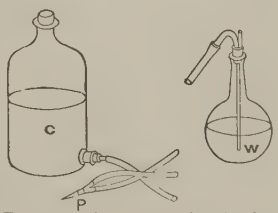

FIG. 21. Apparatus for the investigation of the temperature senses. *C*, cold; *W*, warm water; *P*, metal point.

[1] Degrees C. may be converted into degrees F. by the formula $\frac{9}{5}$ C. + 32 = F.

tensity; it might be described as a solid point of cold. The warm often seems to well up from beneath; it is thinner, more diffuse than the cold, and comes gradually to its full intensity.

The end-organs of temperature may be stimulated either from without or from within: from without, by the application to the skin of a cold or warm object, by radiant heat or the proximity of a cold body, by the action of substances like mustard, pepper, alcohol, menthol; from within, by the organic changes occurring in fever, in extreme fear, in an access of shame, etc. They respond to any decided change of the local level of temperature, the cold organs if the change is negative, and the warmth organs if it is positive. Like the pressure spots, they are tuned to different intensities of stimulus: some warm spots will give only a lukewarm sensation at 40° C., and some cold spots only a cool sensation at 12° C. There are no qualitative differences under the general headings warm and cold.

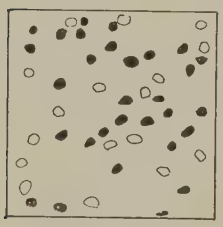

FIG. 22. Cold and warm spots on an area (natural size) of the back of the hand. The dots represent the cold, the circles the warm spots. — M. Blix, 1883.

Cold spots may be found, without difficulty, by help of a lead pencil or a carpenter's spike. The warm spots are less easy of determination: partly because the warmed point quickly cools, and partly because the sensations themselves are duller and less insistent than those of cold. This difference of character makes it probable that the warmth organs are deeper seated than the cold organs. The latter may perhaps be identified with the terminal bulbs of Krause, and the former with the corpuscles of Ruffini.

Temperature spots are found, like pressure spots, over practically the whole extent of the skin. The distribution of the three sets of organs differs in different regions. On the average, there are about 13 cold spots and 2 warm spots to the sq. cm.

It is a curious fact that the cold spots, which are not affected by the stimuli ordinarily used in the determination of warm spots,

give a clear sensation of cold if stimulated by temperatures above 45° C. This has been termed the paradoxical sensation of cold. Why the end-organs of cold should suddenly respond, at this particular temperature, is not known. Paradoxical sensations of warmth, — sensations aroused at the warm spots by a very cold stimulus, — have never been observed in the normal subject. It may be that they do not occur; or it may be that the end-organs are too deeply set in the skin to be reached by a punctiform cold stimulus. In pathological cases of anaesthesia to cold, the patients will occasionally declare that ice, applied to the skin, feels warm. It is, however, doubtful whether such statements do not rest upon a confusion.

If an areal stimulus of 45° C. or over is applied to a part of the skin which includes both cold and warm spots, we have the perception of heat. In general, this appears as a simple and unanalysable quality. It may, however, be analysed by a suitable experimental procedure. Let the stimulus be set, say, at 40° C., and gradually increased. At first we get only the sensation of warmth. With a temperature of some 45°, the paradoxical cold sensation also appears, and grows stronger and stronger as the rising temperature affects more and more of the cold spots. Under these conditions, it is possible, with practice, to distinguish the two component sensations, though each, as the attention turns to it, seems to be coloured by the other.

The temperature senses have a wide range of adaptation. In the winter we grow accustomed to cold, and in the summer to warmth, so that a warm winter's and a cool summer's day are judged by very different standards. Water that at the first plunge seems unpleasantly cold, and a room that strikes us on our entry as oppressively hot, soon become indifferent; we are even surprised at the comments of later arrivals.

Intensive stimuli, of brief duration, give a positive after-image. A long-continued and intensive cold stimulus is

also followed by an after-sensation of cold. The removal of a continued warm stimulus, on the other hand, leaves a sensation of coolness.

It has been found possible, by experiment, to adapt the fingers to a temperature as low as 11° C., so that a stimulus of 12° feels warm, and again to a temperature as high as 39°, so that a slightly lower stimulus feels cold. If the skin is cooled by contact with an object which is kept constantly at 10°, the paradoxical cold sensation will be aroused by a stimulus of 35°, instead of the normal 45°. The following rough experiment gives striking proof of adaptation. Prepare three bowls of water, cold, lukewarm and warm. Hold the hands in the lukewarm water until this feels alike to both. Now place the one hand in the cold, the other in the warm water; let them remain for 1 min. Finally, dip both hands into the lukewarm water: it will seem decidedly cold to the warmed and decidedly warm to the cooled hand.

The after-image of cold following long-continued and intensive cold stimulation is a little paradoxical; we should rather expect an after-sensation of warmth. The cold may, in fact, be the paradoxical cold sensation, aroused in this case by the rush of warm blood to the cold-adapted organs.

§ 41. **The Pain Sense.** — If you hold the shaft of a pin loosely between the forefinger and thumb of the right hand, and bring the point down sharply but lightly upon the back of the left hand, you will sense first the impact itself, and then, after a brief but noticeable interval, something finer, like a prick or a thrill. This second sensation is due to a moderate stimulation of the specific organ of pain.

For accurate results, the skin must be shaved, and softened with soap and water; and the surface must be explored by help of a very delicate hair-point. The sensation obtained from the pain spots then occurs in three stages: first, as a bright, itchy sensation; secondly, as

prick or wiry thrill; and thirdly, as punctiform pain. It is always delicate and lively, and has less body than the sensation of pressure.

The end-organs of pain may be stimulated, from without, by mechanical, thermal, electrical or chemical means. They respond most easily to chemical stimulation, as, for example, to acid

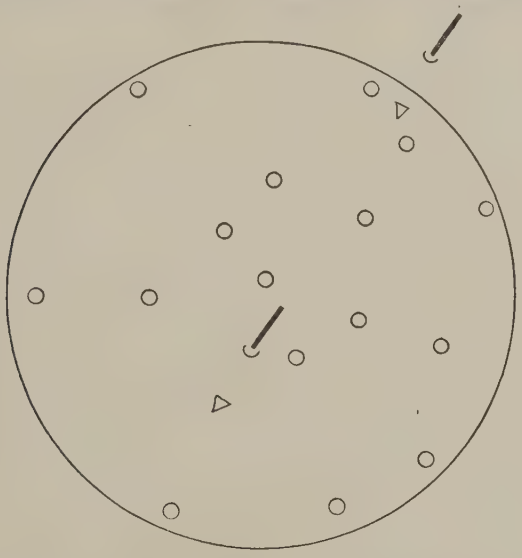

FIG. 23. Pressure and pain spots on an area (here multiplied by 16) of the back of the hand. There are 2 pressure spots and 16 pain spots. The latter are marked as circles, the former as triangles; the hairs to which the pressure spots belong are indicated by the heavy lines and semicircles. — M. von Frey, 1896.

dropped upon the cutaneous surface or to intracutaneous injection of salt solution. They may also be stimulated from within, by the chemical action of substances produced by inflamed tissue. Like the other cutaneous organs, they are tuned to different intensities of stimulus.

Pain spots occur, apparently, over the whole extent of the skin proper. Their distribution does not coincide with that either of the pressure or of the temperature spots. On the average, there

seem to be 100 to 200 pain spots to the sq. cm. With the exception of lips, teeth, and tip of tongue, the mouth cavity shows but little sensitivity to pain; a large area of each cheek is entirely free from pain spots. — The organs of pain are, perhaps, to be found in the free intraepithelial nerve-endings.

The sensation of pain is often blended with sensations of pressure and temperature. The following table gives the facts for the temperature senses:

	Warmth Organs	Cold Organs	Pain Organs
Bitter cold . . .	o	+	+
Cold, cool . . .	o	+	o
Lukewarm, warm . .	+	o	o
Hot	+	+	o
Burning hot . . .	+	+	+

The sensation of prick or pain resembles the sensation of warmth in its slow and gradual rise to full intensity. It resembles those of pressure and cold in its persistence after the removal of stimulus; the prick aroused by the impact of the pin on the back of the hand may last, as positive after-image, for 10 sec. or more.

The pain sense does not appear to show the phenomenon of adaptation. If a pain spot is repeatedly stimulated, the sensation recurs, and presently the surrounding area becomes sore and irritable. It is true that, in everyday life, we learn to disregard pains of moderate intensity, such as muscular soreness or a continued slight rheumatism; but we ignore them, as we ignore distracting noises, because the attention is occupied with other topics, not because they fade out with time.

The dense distribution of the pain spots, the qualitative differentiation of their response to stimulus, and the long duration of

the after-image, account in general for the experiences of cutting, burning, scratching, abrading the skin. Whether they account in detail for all our experiences of cutaneous pain is still an open question. We said above that the granular sensation of pressure is often tinged with a faint ache. If, now, a fold of the skin — say, the fold between the fingers — is grasped firmly with a pair of forceps, the same dull ache appears. The pain in these cases is unlike any superficial pain, but like that of a severe acid burn. It may be, then, that there is another set of pain organs, deeper seated in the skin, whose characteristic sensation should be described as an ache. — The pains derived from subcutaneous tissues are discussed in § 56.

All pains at high intensities are extremely unpleasant or disagreeable. It is therefore only natural that, in ordinary speech, we refer to any very disagreeable experience as painful. But it must be distinctly understood that the sensations proceeding from the pain organs are not necessarily painful, in the sense that they are necessarily disturbing or unpleasant. The bright, itchy sensation and the sensation of prick occur as often as not in indifferent or pleasant complexes; it is only in the third stage, that of punctiform pain, that the sensation hurts. And even here, the pains aroused by minor injuries to the tissues seem in many cases to be insistent, interesting, rather than actually painful.

§ 42. **Theory of the Cutaneous Senses.** — We have seen that the end-organs of the pressure sense[1] are the hair-bulbs and the Meissner corpuscles. How are these organs affected by pressure stimuli? Under what precise conditions are they thrown into function?

If a point is set down upon the skin, the pressure is greatest directly beneath the point, and rapidly decreases

[1] The author knows of no skin-model that is satisfactory for psychological purposes. He uses the three Deyrolle models (*Coupe de la peau de l'intérieur de la main*, *Coupe de la peau montrant l'organisation d'un follicule pileux*, and *Coupe de l'extremité d'un doigt*), upon which the end-organs mentioned in the text have been painted.

with increase of distance from it, — whether the distance be measured laterally, upon the surface of the skin, or vertically, into its substance. In other words, the point coincides with the maximum of what we may call a gradient of pressure. The gradient will be steep or gentle, according as the stimulus is strong or weak; it will take shape slowly or quickly, according as the point is applied gradually or with sudden impact.

Experiments show that the quick formation of such a pressure gradient is the adequate stimulus to the pressure organs. They show also that the gradient may be positive or negative; the pressure spots respond to pull as well as to pressure. It is not easy to say just what changes occur in the skin as the gradient is formed. There must, however, be a redistribution of the liquid contained in the tissues, and there may be local concentration; probably, therefore, the mechanical effect of pressure upon the surface of the skin is translated into a chemical action upon the end-organs.

Reference to the pressure gradient enables us to explain two observations which have aroused much discussion among psychologists. If the hand is dipped into water, or even into mercury, no pressure is sensed over the immersed area, but there is a distinct ring of pressure sensation at the place of emergence. The reason is, evidently, that here and here only does a noticeable pressure gradient occur. Again, if two objects of the same weight but of different size are laid successively upon the resting skin, the smaller appears the heavier. The reason is that the pressure gradient is steeper for the smaller, and more gentle for the larger object.

No theory of the temperature senses can as yet be offered; we have not even identified, with certainty, the terminal organs through which the sensations are aroused.

If, as seems probable, the organs of the pain sense are represented by the free nerve-endings of the epidermis, we have to account for the fact that the deeper-lying pressure spots are more readily stimulated by contact with material objects than the superficial pain spots. The reason lies in the nature of the cutaneous tissues. The epidermis is hard and inelastic, like a board; the cutis is soft and elastic, like sponge rubber. Hence, under ordinary circumstances, the stimulus is transmitted to the cutis, while the epidermis is not affected. When the epidermis is pierced by a fine point, or the dead cells of the outermost layer are cleared away and the tissue softened by soap and water, the superficial pain organs respond earlier than the organs of pressure.

§ 43. **Tickle and Itch.** — We described the sensation of contact as being somewhat ticklish, and the weak sensation of prick as being itchy. It would seem, then, that our everyday experiences of tickling and itching might be referred to a diffuse stimulation of the pressure spots and pain spots.

We get tickle, as a matter of fact, by brushing lightly, as with a feather, over a field of hairs. But we also get it, much more insistently, by brushing over a hairless surface, such as the red area of the lips, the palm of the hand, or the sole of the foot. The sense quality appears to be the same in the two cases. It is not quite easy to see how the pressure spots in the hairless regions can be stimulated by a contact which is too light to deform the skin: possibly, however, the application of the stimulus changes the pressure of blood in the superficial capillaries, and the nerve-endings are thus indirectly affected. The tickle that occurs when you are seized under the arms, or clutched on

the knee, appears deeper-seated than the tickle produced by brushing the skin.

Itching may be referred with some confidence to the organs of cutaneous pain. It is the result of certain skin-diseases, of superficial wounds and burns, of the bite of insects, etc., — that is, of conditions by which the nerve-endings of the epidermis are directly affected.

It is often stated, as a paradox, that tickling makes us laugh, and is therefore pleasant, while it also makes us try to get away, and is therefore unpleasant. Such a statement is, however, far too simple for the facts. Tickling may be either pleasant or unpleasant, according to the region of the skin affected, the mode of application of stimulus, and the mood of the person tickled. Thus, it may be said in general that tickling on the sole of the foot or at the hairy orifices of nose and ear is distinctly unpleasant, while tickling on the palm of the hand or under the arm-pits is rather pleasant. Yet the flexing of the foot may change the unpleasant into a pleasant experience, and tickle on the palm may be almost unbearably disagreeable. The arousal of laughter, again, is extremely capricious. We can tickle ourselves, and get precisely the same sensations as when we are tickled by some one else; but we never make ourselves laugh. Nor can any rule be laid down as to the provocation of laughter by a certain form of stimulus, by stimulation of certain areas of the skin, etc. What holds of one person does not hold of another, or of the same person in a different mood. And the movements of escape are equally variable: a child may ask to be tickled to-day, and may beg not to be tickled to-morrow; a part of the body that is pleasurably ticklish in one child may be unpleasantly ticklish in another, and so on.

All this variety of detail means that the tickle-stimulus does not act simply upon the sense-organ, as a colour-stimulus acts upon the eye, but that it serves as the trigger, so to speak, to release certain inherited mechanisms of our nervous system. These mechanisms are, however, themselves liable to modification or

arrest from higher nervous centres, so that they are not touched off inevitably or with uniform result. The reason for such a physiological arrangement can only be guessed at. It is significant that the areas which are especially ticklish are highly vulnerable: in nearly all of them some important structure, such as a large artery, is close to the surface; and where this is not the case, as in the sole and the palm, an injury, even if not serious, is seriously disabling to the organism. It may be, then, that tickling represents a very old form of race-play, the play of combat. The movements of attack and of defence are playful forms of fighting, and the laughter shows that the whole affair is a friendly game. This interpretation is, of course, speculative. Nevertheless, it accounts on the ground of utility for the persistence of the motor responses to tickling, while it also leaves room for their variety and uncertainty in our own case. On the whole, it probably comes as near the truth as, in the absence of exact data, we can expect any theory to bring us.

References for Further Reading

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KINAESTHETIC SENSES

§ 44. **The Kinaesthetic Senses.** — In passing from the special senses to the group of organic sensations, we naturally turn first to the internal senses which are commonly included in the sense of touch. These senses have their organs in the motor apparatus of the body; they are set in function by bodily movements; they enable us, without help from the eye, to judge of the position and movement of our limbs. Hence they have been termed, collectively, the kinaesthetic senses.[1]

The nature of the tissues which make up the motor apparatus, and the distribution of sense-organs within them, may be understood from the following illustration. Think of two long bones, which form a ball and socket joint, and of a single muscle, which passes across the joint and is attached by its tendons to the shafts of the bones. The opposed surfaces of the joint are covered with cartilage. This thins out, at its margin, into a layer of vascular connective tissue, the periosteum, which extends over the entire shaft. The joint is enclosed in a capsule of ligament; the inner surface of the capsule and the inner faces of the articular cartilages are lined with synovial or lubricating membrane. The muscle is composed of bundles of muscle fibres; it is divided into compartments by fascial or sheathing tissue, and is invested by a thicker sheath of the same material. The tendons are strong, fibrous cords, directly continuous at the one end with the fascia of the muscle and at the other with the periosteum of the bone.

[1] The term was suggested by H. C. Bastian. See *The Brain as an Organ of Mind*, 1885, 543.

The muscles and tendons contain peculiar end-organs, known respectively as the muscle spindles and the spindles of Golgi. Pacinian corpuscles, or similar structures, have been found in fascial tissue, in ligament, in the synovial membrane, and in the periosteum of certain bones. Sensory nerve-endings occur also in the substance of the bony tissue. The sensitivity of the bone extends, apparently, up to the margin of the articular cartilages; whether it extends farther, so that the surface of the joint beneath the cartilage is sensitive, we do not know.

In everyday life, the sensations of the kinaesthetic senses occur only as factors in what we may call touch-blends. In all such experiences as lifting, holding, grasping, pushing, pulling, moving, handling, writing, playing a musical instrument, tying a knot, they are fused or blended with sensations from the skin. It is not surprising, then, that the skin should itself come to be looked upon as an active or motor organ, and should be credited with sense-qualities which are really derived from the deeper-lying tissues. The very fact that the motor apparatus is covered by the skin, that under normal conditions it cannot be separately stimulated, favours this confusion. Besides, the kinaesthetic sensations are, in general, very like the cutaneous: in one case, indeed, they seem to be indistinguishable from cutaneous pressure. For this reason, some psychologists still describe them as sensations of internal touch.

Nevertheless, the distinction between the sensitivity of the skin and that of the underlying tissues was drawn very early in psychology. Aristotle seems to have had an inkling of the difference, and it was clearly recognised in the sixteenth century.[1] Modern writers have usually

[1] Aristotle appears in general to bracket cutaneous and kinaesthetic sensations together, under the heading of touch. He does, however, say, in the *Mu-*

ascribed the deeper-seated sensations to the muscles, and the muscular sense has accordingly been added, as a sixth sense, to the list of sight, hearing, taste, smell and touch. We have learned, however, that this list is itself incomplete; and recent experiments, coupled with the study of pathological cases of partial anaesthesia, show that the muscles are but one, and that by no means the most important, of a number of sensitive tissues.

§ 45. **The Muscular Sense.** — To bring out the special quality of muscular sensation, we must find a method of stimulating the muscle alone, that is, independently of skin, tendon and joint. The best way is to lay out the arm on a support; to render the skin and the subcutaneous connective tissue anaesthetic by cocaine injection or ether spray; and then to press down upon the body of the muscle. The result is, first, a sensation which is described as dull, dead, diffuse; it is simple in nature, cannot be named, but suggests areal pressure upon the skin. With increasing intensity of stimulus, the sensation takes on a dragging character: sometimes there seems to be a hard, dead lump in the muscle, sometimes the muscle fibres seem to be ground or rolled against one another. The general impression is that of a tired, overworked limb. Finally, the dragging sensation becomes sore, achy, and the whole experience passes into dull pain.

The same series of sensations appears if a muscle is thrown into forced contraction by the electric current. Indeed, after a short

tory of Animals: "The sense of touch resides in the simple parts, as in the flesh; . . . the capacity of action resides in the compound parts, as . . . the power of locomotion in the feet or wings." For an historical discussion of the subject, see T. Reid's *Works*, ed. by W. Hamilton, ii., 1872, 867, note II.

practice in the laboratory, it is easy to identify the different stages, by introspection, in everyday life.

As the possible seat of muscular sensations, we have the fascial corpuscles and the muscle spindles. It is probable, from what we know of the joints (§ 47), that the corpuscles mediate a sort of pressure sensation. We may, then, provisionally, ascribe to them the dull, diffuse sensation, and to the spindles the dragging, sore, tired sensation that ultimately becomes pain.

§ 46. **The Tendinous Sense.** — In all cases of severe or prolonged muscular work, we get a sensation which cannot be identified with any one of those derived from muscle. Where we are ourselves active, as in wrestling, pushing, pulling, lifting, we term it effort or exertion; where we are passive, as in supporting a weight, or standing for a long time on one leg, we term it strain. The quality is the same throughout.

This sensation of strain appears to come from the tendons, and to have its organs in the spindles of Golgi. Like the dragging sensation from the muscles, it passes over, at high intensities of stimulus, into dull pain.

Tendinous tissue is, as we have said, directly continuous with the muscle fascia and with the periosteum. It is therefore impossible to isolate the tendon for separate stimulation. In seeking to discover the nature of tendinous sensation, we can only rule out the qualities that come from skin, muscle and joint, and note what is left. The remainder turns out to be the sensation of strain. Having reached this result, we find it confirmed by the intimate connection of strain with muscular fatigue and muscular pain, and by the tendency to localise these sensations together in the substance of the limb. —

There are, further, certain experiences which seem to depend upon the cooperation of end-organs in muscle and tendon. When we are feeling particularly well, we move lightly, springily,

jauntily; and if we try to analyse the feeling, we notice light, thrilling sensations, which appear to come from the skeletal muscles, and are most marked in the calves of the legs. Again, if we are feeling excited, and try to analyse that feeling, we soon come upon similar bright sensations, most marked in the thighs. Now corpuscles, of the same kind as those of the muscle fasciae and the capsules of the joints, are found in the sheaths and substance of the tendons, and sparsely in the substance of the muscles. They occur also in the sheaths of certain nerve-trunks, and near large vessels. In a word, they represent a widely distributed type of sense-organ. Since the sensations mentioned above are also distributed over a wide area, and since they closely resemble the sensations set up by movement in the joints, we may suppose that they are due to a weak stimulation of the corpuscles. Against this conclusion stands the dull, dead character of the sensation which is produced by pressure on the body of the muscle, and which we have ascribed to the corpuscles of the fasciae. It must, however, be remembered that the stimulus here employed is both unnatural and severe. As the pressure spots of the skin give first a bright sensation of contact, and then a sensation of more solid pressure, so may these corpuscular end-organs give first the light, thrilling experiences of health and excitement, and at higher intensities of stimulus something that is duller and harder.

§ 47. **The Articular Sense.** — If the hand is moved slowly to and fro at the wrist with fingers outspread, while the eyes remain closed, we have, besides the visual image of the movement, various sensations from the skin. There is probably a sense of coolness over the palm; and there are waves of diffused pressure, now across the knuckles, now down the front of the forefinger, now on the sides of the fingers, as the tension of the skin changes. Subcutaneous sensations from the body of the hand, if remarked at all, are exceedingly faint: there is no trace of

strain, and hardly a trace of muscular sensation. We notice, however, a rather massive complex of sensations in the wrist-joint, whose quality is not distinguishable from that of cutaneous pressure.

These sensations come, predominantly, from the end-organs of the articular ligaments. The general impression is the same as that produced by moving the finger over a greasy surface of indifferent temperature; or, better, by smearing a finger of the right hand with vaseline and turning it in the loosely closed left hand. Sensations of like quality are derived from the sensitive surfaces of the bones, around or beneath the articular cartilages. They may be brought out by pressing a finger strongly down into its socket, and in this position moving it back and forth.

The corpuscles are distributed most thickly on the flexor side of the articular capsule, and it is easy to see that they must be stimulated by the tensions and compressions of the tissue as the limb is moved. The corpuscles of the synovial membrane and of the ligaments that, in some joints, run between the articular surfaces may be stimulated either by movement or, like the surfaces of the bones, by pressure and counterpressure within the joint itself. —

The last few sections have raised a question which recurs throughout the study of organic sensation: the question whether we may assume that every sensory end-organ is an organ of sense. It seems natural to reply in the affirmative. If the hair-bulbs, and Meissner's corpuscles, and the free nerve-endings of the epidermis, and such and such other structures furnish sensations, why not all the rest of them? Nevertheless, a decision is not easy. In the skin, for instance, there are many such organs — Ruffini's plumes, Tomsa's knots, Merkel's cells — which cannot with certainty, even with probability, be brought into connection with sensations. As histological research advances, more and more of these structures are brought to light. Either they are, in large

measure, mere reflex mechanisms, or they are sense-organs which, despite differences of form, yield the same quality of sensation. The second of these hypotheses is, perhaps, the more probable. Differences of form may be attributable to local differences of nutrition and of the conditions of development at large; indeed, several of the corpuscles figured by histologists seem to be related as terms of a single developmental process.

§ 48. **Movement and Position, Resistance and Weight.** — We are able, with closed eyes, to tell pretty accurately in which direction a limb moves and how far it travels. We are also able, as a rule, to describe the position of an unmoved limb. These perceptions of movement and position are based upon the articular sensations discussed in the preceding section.

It seems clear, on general principles, that the perception of movement cannot come by way of muscle and tendon. For movements of equal range and of like direction may be made with the limb bent in or stretched out, heavily weighted or held free: that is to say, similar movements may involve very different degrees of muscular and tendinous sensation. It is hardly possible that a reliable set of perceptions of movement could be built upon so instable a foundation. Moreover, experiment shows that we estimate passive movements as correctly as active; it makes no difference whether the arm, for instance, is laid on a rest and moved by someone else or whether we hold it out and make the movement for ourselves. The perception of movement is, then, as a matter of fact, independent of changes in muscle and tendon.

There is also positive evidence to connect the perception of movement with the joints. In the first place, skin, muscle and joint may be rendered partially anaesthetic by faradisation, that is, by the repeated passage of electrical shocks through them. If, now, the skin and muscles are thus treated, the perception of movement is not affected; if, however, the joints are anaesthetised, it is very considerably impaired. Secondly, there are diseases

which bring with them anaesthesia of the skin, or of skin and muscles together, or of the whole surface and substance of a limb. In the former, the perceptions of movement and position are normal; where the muscles are involved, they are not inadequate; but where the joints are also insensitive, the patients can neither adjust their movements nor judge of the position of the diseased limb without the aid of sight.

It may be objected to this view that we are aware of certain movements — movements of tongue, lips, eyeballs — in which the joints are not concerned. That is true. It must, however, be remembered that tongue and lips play against fixed structures, the roof of the mouth and the teeth; and it is, in fact, mainly by reference to these that their movements are estimated. One has only to hold the tongue free in the mouth cavity, and to watch its movements in a mirror, to be convinced that an organ which has only skin and muscle to rely upon is exceedingly obtuse as regards the perception of movement. With the eye things are different. The eyeball turns on the fatty cushion of the orbit very much as the ball of a joint turns in its socket. We thus get a true perception of movement of the eyes, although the sensations are dulled and weakened by the yielding nature of the tissues.—

We have spoken throughout of the perception of movement: there is no such thing as a specific movement sensation. What happens is that a complex of articular sensations becomes associated, with constant repetition, to a visual perception of a movement. The association is, in course of time, so firmly established that the occurrence of the articular complex calls up, even with closed eyes, a visual idea of the displacement of the limb. Position is perceived in the same way. When a limb comes to rest, there is a certain final distribution of tensions and compressions in the ligaments of the joints, which gives rise to a complex of sensations. So long as these persist, we can call up a visual idea of the position of the limb. When they fade out, by adaptation, we lose the visual idea along with them, and can recover the perception of position only by making movements which bring the articular end-organs into renewed function. We have all had the experience, on waking from a sound sleep, of a blank loss of arm

or leg: for a moment, we cannot imagine where the thing is. A slight shift of position puts us to rights again.

When we lift a weight, we are working against the force of gravitation; when we overcome a resistance, we are working against mechanical forces in some other direction. The perceptions of weight and resistance seem to be of the same order, psychologically, as their objects are of the same order physically. Their organs are, in the first instance, the sensitive surfaces of the joints. When strain or exertion is involved, the spindles of the tendons also come into play.

The perception of weight may be either passive or active. If the arm is laid out upon a table, and a heavy object placed upon the skin, we have the passive perception: the organs affected are the pressure spots of the skin, and the Pacinian corpuscles of the subcutaneous connective tissue and the muscle fasciae. Under these circumstances, our discrimination of weight is inaccurate; it corresponds to the perception of movement by tongue or lips. When the weight is lifted, and the perception thus becomes active, discrimination is much more delicate; it corresponds to the articular perception of movement.

Some psychologists separate the perception of weight from that of resistance, and refer the former to the tendons and the latter alone to the articular surfaces. And indeed it seems natural, at first thought, to say that the pull of a weight must draw the surfaces of the joint apart, while the resistance of an inert body must jam them together. Really, however, the very fact that the arm is braced and set for lifting means that it is strongly bound at the joints; and the heavier the weight to be raised, the greater is the articular pressure. Moreover, it makes little difference in the perception of lifted weights whether the arm is flexed or extended, whether the hand grasps the object loosely or tightly; so that the perception is, at least in some degree, independent of the state of the tendons.

Again, some psychologists hold that the sensitive surfaces of the bones play a large part in the perception of movement. The surfaces must, of course, rub against each other as the limb is moved; and we know that patients who suffer from anaesthesia of skin and muscles perceive movement and position more accurately when the joints are pressed together than when they are pulled apart. On the other hand, the rubbing can be but light in the case of passive movements, where we are relieved of the weight of the limb. And it is possible, in the pathological conditions, that the sensations from the bones serve, by adding to the sum of articular sensation in general, simply to call the patients' attention to the diseased limb, without contributing directly to their perception of its movement. The strongest bit of negative evidence lies, however, in the fact that we may get the same perception of movement with very different accompaniments of resistance. —

Here as before it is important to remember that we are dealing not with sensations but with perceptions. In movement, we have a complex of sensations from the joint capsule, along with varying sensations from skin, muscle, tendon and articular surface. In weight and resistance, we have a complex of sensations from the articular surfaces, coloured at high intensities of stimulus by tendinous strain, along with varying sensations from skin, muscle and joint capsule. There is no specific sensation of weight or of resistance.

§ 49. **The Alleged Sensation of Innervation.** — We have so far taken it for granted that sensations are due to the action of stimuli upon a sense-organ. Light falls on the eye, or a contraction of the muscle fibres squeezes the muscle spindles; the excitation thus started is carried, by afferent sensory nerves, to the brain; and we get the sensation of colour or of fatigue. The course of the nerve process which arouses sensation is always from without inwards, from periphery to centre.

There is, however, one case — that of the sensation of effort or exertion — in which this view has been challenged. We have ascribed the sensation to the Golgi spindles (§ 46), and have thus put it upon the same plane with all other sensations. Some psychologists believe, on the contrary, that it is an outgoing sensation, due to the discharge of motor excitations from brain to muscle. Its nerve process would then run from within outwards, from centre to periphery.

The arguments are drawn, in the main, from pathology. A patient who cannot move a leg, or who cannot turn his right eye outwards, may nevertheless believe that he has made these movements; he will assure his physician that he feels the weight of the moved limb, or the turn of the eyeball in the orbit. Since no movement is made, these sensations must, apparently, come from the centre, must accompany the outgoing current of innervation.

We notice, however, in observing such patients, that the effort to move the diseased leg always means a shift of the hips, and various jerks and twitches in the sound leg; and that the effort to move the right eye always means actual movement of the left. Here, then, are sources of kinaesthetic sensation which might easily give the illusion of movement in the unmoved part. Besides, there are pathological facts to be quoted on the other side. In certain diseases, a patient may make quite extensive movements of the limbs, without being aware of the fact; indeed, he is surprised, when his glance falls upon arm or leg, to find that it has changed its position. Since these movements are made, they must have been innervated; since they are made unconsciously, the innervation cannot have aroused any sensation of effort.

The following experiment tells very strongly against the existence of the innervation sensation. If two objects of the same weight but of different size are lifted successively in the closed hand, or even if they are lifted by a string attached to the finger, the smaller appears the heavier. The observer may have seen them weighed, and may be convinced that the weights are physically equal: nevertheless, the illusion persists. If, now, the judgment of weight depended upon a sensation of innervation, this result would be impossible: the observer, knowing that the same amount of energy is required to raise both objects, would innervate his muscles to the same degree.

We explained a similar illusion of the resting skin (§ 42) by the difference in the slope of the pressure gradient. This factor is here replaced by visual association. In the vast majority of cases, the larger of two like objects is also the heavier. Hence we have learned to interpret size as weight; when we see a large thing, we unconsciously innervate the muscles for a heavy thing. The association holds, in spite of our knowledge that the weights are equal: we lift the larger object as if it were heavy, the smaller as if it were light. The former then flies up, giving us the kinaesthetic sensations that light things arouse, and we judge it to be lighter than its companion.

§ 50. **Some Touch-blends.** — We are now able to analyse the touch-blends mentioned in § 39. The difference between hard and soft, for instance, is mainly a difference in degree of resistance offered to the hand; and this means a difference in the degree of pressure exerted by the one articular surface upon the other. The distinction thus belongs to the joints rather than to the skin. Again, the difference between smooth and rough is a difference, first, between continuous and interrupted movement, and secondly between uniform and variable stimulation of the pressure spots of the skin. The distinction thus belongs to joints and skin together.

Sharp and blunt differ, primarily, as pain and pressure: a thing is sharp if it pricks or cuts, blunt if it sets up diffuse pressure sensations. Here, however, as in all the touch-blends, visual association plays a very large part.

Wetness is a complex of pressure and temperature. It is possible, under experimental conditions, to evoke the perception of wetness from perfectly dry things, — flour, lycopodium powder, cotton wool, discs of metal; and it is possible, on the other hand, to wet the skin with water and to evoke the perception of a dry pressure or a dry temperature. Not the moistening of the skin, but the fitting distribution of pressure and temperature sensations, gives rise to the perception of wetness. Other modes of distribution of the same sensations produce the perception of dryness.

Clamminess is a mixture of cold and soft: the cold sensations and the pressure elements in the softness must be so distributed as to give the perception of moisture. The clammy feel of a wet cloth may be got by laying the finger on a loosely stretched rubber membrane, and sending a puff of cold air over it at the moment of contact. Oiliness is probably due to a certain combination of smoothness and resistance; movement seems to be necessary to its perception. Clinging, sticky feels may be obtained from dry cotton wool.

References for Further Reading

§§ 44–50. A. Goldscheider, *Gesammelte Abhandlungen*, ii., 1898; V. Henri, *Revue générale sur le sens musculaire*, in *L'Année psychologique, 5me année*, 1899, 399; C. S. Sherrington, *The Muscular Sense*, in Schäfer's *Text-book*, ii., 1900, 1002 ff.; I. M. Bentley, *The Synthetic Experiment*, in *American Journal of Psychology*, xi., 1900, 414 ff.; R. S. Woodworth, *Le Mouvement*, 1903; W. Nagel, *Die Lage-, Bewegungs- und Widerstandsempfindungen*, in Nagel's *Handbuch*, iii., 1905, 735 ff.

§ 51. **The Kinaesthetic Organs of the Internal Ear.** — We have found, in the capsules of the joints, organs which receive their stimulation from movement of the limbs, and which give us the perceptions of movement and position of these members. We have now to consider certain structures of the internal ear, which represent kinaesthetic organs of a different kind. They are stimulated mechanically, by the acceleration of a mass-movement through gravitation, inertia or centrifugal force, and they give us the perceptions of movement and position of the head and, perhaps, of the whole body. They are known as the cristae ampullares of the semicircular canals, and the maculae acusticae of the vestibule.

In § 28 we dealt with the cochlea of the internal ear, the part of the membranous labyrinth which forms the end-organ of the cochlear nerve and furnishes sensations of hearing. We are now to discuss the function of the remaining portion, the vestibule and the semicircular canals, which together form the end-organ of the vestibular nerve.[1] There are five cell-groups, in each ear, to which the fibres of this nerve are distributed: the maculae of the utricle and saccule, the two divisions of the vestibule; and the cristae in the ampullar enlargements of the three semicircular canals. Maculae and cristae are all of the same general type: there is a local thickening of the membranous wall, upon which rests a little field of hair-cells. In the maculae, however, the hairs support a mass of tiny crystals of carbonate of lime, the otolith; in the cristae, they project freely, like a camel's-hair brush, into the ampullar cavities. The otoliths are enclosed in a homogeneous, viscous substance, which also interpenetrates and surrounds the ampullar hairs. The mass which is moved in the maculae is, therefore, the otolith; in the cristae it is the cemented brush-like structure, which has been termed the cupula. —

[1] In addition to the models of the internal ear mentioned on p. 109, Exner's Bogengangmodell (shown in Fig. 24, p. 177) and Otolithenmodell will be found useful for demonstration.

The study of the semicircular canals and the vestibule presents a curious difficulty to psychology, a difficulty the reverse of that which we have just met in our discussion of the sensitivity of muscle, tendon and joint. There, we had a tangled complex of sensations, and the problem was to distribute them among the available end-organs. Here, we have highly developed end-organs, but no very obvious group of sensations to refer to them. Moreover, there can be no doubt that the functions of the vestibular nerve are, in large measure, reflex: by virtue of its cerebellar connections it plays a large part in the regulation of what one may call the tone of the muscular system; the impulses normally proceeding from it keep the muscles trim and braced, while the cutting off of these impulses has an atonic effect similar to that produced by section of the dorsal roots of the myel. Under these circumstances, it is not surprising that different investigators should take very different views of the kinaesthetic importance of cristae and maculae. The following sections, however, represent the general trend of current psychological opinion.

§ 52. **The Ampullar Sense.**— If you turn round rapidly upon the heels several times in succession, and then come to rest with closed eyes, you have a sensation which can only be described as a swimming in the head. Its apparent direction is opposed to the direction of the actual movement, so that it wears the appearance of a negative after-image. Having once noticed it, you are afterwards able to notice, as you begin to turn, a swimming whose direction is the same as that of the movement of rotation. The sensation seems to circle through the head, and its plane changes with change of the head's position. If, for instance, you turn round with the head bent forwards on the chest, and suddenly raise it to the normal attitude after you have stood still, the plane of the swimming changes, as suddenly, from horizontal to transverse vertical; if you

turn with the head inclined on the shoulder, and raise it afterwards in the same way, the plane changes from horizontal to sagittal.

This swimming sensation, which with practice may be observed to follow a quick movement of the head in any direction, comes from the cristae of the semicircular canals. At high intensities, it passes into dizziness or vertigo.

It is significant that we find the canals fully formed, and conjoined with a merely rudimentary cochlea, in animals, such as birds and fishes, which have to balance in the surrounding medium. Their size and accessibility, in these lower vertebrates, makes experiment easy: the canals may be severed, plugged, or extirpated without further injury to the organism. If, now, a single canal is cut, say, in a pigeon, we note, as the result of the operation, a general slackening of the whole muscular system, and also a disturbance of movement in the plane of the severed canal. On the one hand, the bird seems weakened: its flight is feeble, its legs bend inwards; on the other, it is subject to certain forced movements. If, for instance, the right horizontal canal is cut, the pigeon keeps up a pendular motion of the head sidewise, to the right and back again; it also tends, in walking, to bend to the right and so to circle round and round, instead of moving straight forward. These symptoms vary with the extent and the standing of the injury. Where the lesion is one-sided, there may presently be complete recovery; if both sets of canals are extirpated, the muscular weakness may end in general muscular atrophy, and all coordinated movements are thrown into confusion.

It is clear, then, that the canals constitute an organ which serves to regulate the tone of the muscular system. But it seems clear, also, that they stand in a special relation to movements of the head. Injury done them not only cuts off the tonic impulses, but in addition gives rise to abnormal impulses which arouse the abnormal movements. This dynamic function might, like the tonic, be reflex. Probably, however, it is attended by sensation, the quality of which is lost to ordinary observation in the complex

of cutaneous and kinaesthetic sensations which we have described in previous sections.

The evidence for sensation comes partly from experiments made upon the normal human subject, and partly from pathology. Experiments upon rotation, carried out under strict conditions, reveal the swimming and dizziness of which we have spoken. Similar sensations are evoked by syringing the ear, or passing an electric current through it. Further, it is found that about half of the deaf-mutes in our large institutions cannot be made dizzy by rotation; they do not stagger when the movement ceases, nor do they show the compensatory twitching of the eyes which is normally a symptom of dizziness. Now, autopsy proves that in about 50 per cent. of deaf-mute ears there is lesion or degeneration, not of the cochlea alone, but of the whole internal ear. This correspondence furnishes a strong argument for referring the sensation of dizziness to the canals.

§ 53. **Theory of the Ampullar Sense.** — The three semicircular canals of each ear are set, approximately, in the three dimensions of space. They are also set symmetrically in the two ears: the horizontal canals in the same horizontal plane, and the posterior of the one side and the anterior of the other side in parallel planes. It is thus clear that any movement of the head, whatever its direction, must affect the canals. If it is made in a plane which coincides with the plane of a canal, then that canal alone will be stimulated; otherwise, two or more canals will be involved, in different degrees, on the principle of the parallelogram of forces.

Suppose, then, that we are subjected to a rotary motion in the horizontal plane. When the turning begins, the water in the horizontal canal lags behind the containing tube; the back thrust of the water bends the cupula; and the nerves of the crista are stimulated. We have the swimming sensation. As the turning

continues, the water takes up the motion of the canal, and the cupula recovers its equilibrium. When we stop, the water in the tube shoots forward, bending the cupula in the opposite direction; and we have the reversed swimming sensation, which continues until the ampullar organ comes to rest in its normal position.

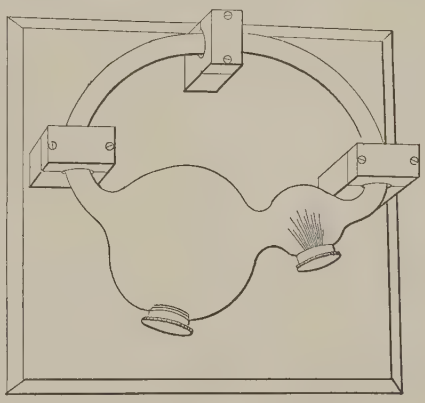

FIG. 24. Exner's Model of a Semicircular Canal.

Precisely the same thing happens if we turn round voluntarily on the heels, and precisely the same sort of stimulation is set up, in the other canals, by movements in other planes. —

The quality of the ampullar sensation, at low intensities, is most like that of a diffused pressure. The direction of the swimming is not directly sensed, but depends upon association.

Dizziness usually occurs in a very complicated setting. When we have turned upon the heels, and have come to a sudden stop, the kinaesthetic sensations from the limbs are so disposed as to give the perception of a certain position. On the other hand, the swimming in the head, and the arrest of the soft viscera by the body wall, give the perception of a movement in the opposite direction. Further, if the eyes are opened, the objects about us seem to be revolving in the same direction as that of our original movement. Here, then, is a conflict, so to say, of three different perceptions: the limbs are at rest, the body is moving one way, and the outside world is moving another way. Oftentimes, to make things still worse, nausea is added.

Under these conditions, introspection is very difficult. Some psychologists deny the sensory character of dizziness altogether, and regard it as the resultant of the conflicting perceptions. Since, however, it may be set up by such local stimuli as the passage of

an electric current through the ear, it appears to be referable to the ampullar organs. Moreover, there can be no doubt that the sensation in the head, as we turn it sharply to one side or start to turn round, is from the first swimmy, faintly dizzy, so that dizziness would seem to be the quality natural to it at high intensities.

§ 54. **The Vestibular Sense.** — The sensory function of the maculae is still somewhat problematical. It appears, however, that they play a part in our perceptions of the position of the body as a whole, and possibly of rectilinear movements of the body in space, more especially when these perceptions refer to the vertical dimension. —

We have noticed that the people who ride on merry-go-rounds at fairs lean inwards, as the speed of rotation increases; they shift their balance, to avoid flying off at a tangent. This is natural enough. What is curious is that, provided the eyes are closed, the riders think that they are sitting uniformly upright. If they are asked to hold a stick before them, vertically, as they revolve, they hold it at a slant; their perception of the vertical has changed. Again, we have noticed that, when the body is immersed in water, as in diving or in swimming beneath the surface, there is never any doubt as to which direction is up and which down. No one with normal sense-organs has ever been drowned by swimming to the bottom when he intended to come to the top of the water.

These perceptions are noteworthy when we compare them with the behaviour of the deaf-mutes who lack the sensation of dizziness. If such persons are placed upon a merry-go-round, they do not adjust themselves to a new vertical. They sit bolt upright, and hold the stick to the true vertical; they must be tied, or they are thrown off by centrifugal force. And it is dangerous for them to bathe

in deep water, even if they know how to swim, because, once they are immersed, they lose the perceptions of up and down, and may drown from sheer confusion of directions.

It seems, then, that we must have some source of perception which the deaf-mutes are without; and it is natural to look for it in the vestibular organs. Many psychologists believe that the maculae furnish sensations of pressure, which, under favourable conditions, may be separately distinguished by introspection.—

Most of us have noticed, again, as we lay in a sleeping car or were carried in an express lift to the top of a high building, that there were parts of the journey during which the perception of movement altogether disappeared. The eyes must, of course, be closed; there must be no draught of air to suggest that we are moving; and the motion itself must be smooth and uninterrupted. Under these conditions, a movement of the body forwards or backwards, up or down, is not perceived, so long as its rate remains the same. Let the rate change, however: let the car slow or quicken its speed: and we are at once aware of our passage through space.

Some psychologists believe that whenever there is acceleration, positive or negative, of the rate at which the body is travelling, the maculae are brought into action; while, so long as the rate is uniform, they adapt themselves to it, as the ampullar organs adapt themselves to uniform movement of rotation. If the movement is in the horizontal plane, forward, backward or sidewise, the vestibular sensations are ordinarily swamped in the mass of sensations from skin, muscle, tendon and joint. If, on the other hand, it is in the vertical plane,—as in going up or down in a

lift, tobogganing, dropping off a high place, swinging,— the sensations appear as a compression or lightness in the head. Like the ampullar sensations, they are often clearest in the form of negative after-images: when a rising lift suddenly comes to a standstill, we have a distinct feeling of squeeze in the region of the ears.

§ 55. **Theory of the Vestibular Sense.** — The maculae function in much the same way as the cristae. The otoliths which are suspended above the fields of hair-cells correspond to the water in the canals; they lag behind, as the supporting structure moves away, and they overshoot or press down upon their support when the movement is arrested. The two maculae of each ear are so situated that the lines of displacement of the otoliths are at right angles to each other; the one moves in a horizontal plane, which slopes at an angle of some 45° from before backward, and the other in a sagittal plane, which slopes at the same angle from behind forward. They are thus affected, on the principle of the parallelogram of forces, by movements in any spatial dimension.

Applied to the changed perception of the vertical on the merry-go-round, this theory means that the centrifugal force shifts the otoliths outwards; they glide into the position that they would naturally assume if one were really leaning outwards with the body at rest. The true vertical thus seems to slant out, and an effort to restore it means a bend inwards. A like explanation holds of the perception of direction under water; the pressure or pull of the otoliths tells us whether we are head-up or head-down. Destruction or atrophy of the organs would then lead to those insufficiencies of perception which we note in the deaf-mutes.

Whether we may appeal to displacement of the otoliths for the perception of acceleration of movement in the horizontal

plane depends upon the degree of inertia which they possess. Since this is not known, any hypothesis would be merely guess-work. There is, however, no introspective evidence of their function, as there seems to be in the case of rectilinear vertical movements of the body. —

Otolith organs have a very wide range in the animal kingdom, a range that extends from the jelly-fish to man. Their functions appear to be, from the first, tonic and static. It has been found possible, for instance, to replace the otolith of a crustacean, which sheds the contents of the otocyst at the same time that it sheds the skin, by a mass of fine iron-filings. When the artificial otolith is approached by an electromagnet, and the circuit closed, the animal assumes a peculiar position which is directly due to the stimulation of the organ. On the other hand, the otolith sac is the precursor of the organ of hearing, and this fact has been made much of in theories of its function. It has been suggested, for instance, that the maculae of our own ears give the sensations of noise, and possibly of shrill, chirping tones, and that the cristae give us the perception of the direction from which sounds come. There is no evidence for either view. Again, it has been found that the hairs which support the otolith are, at least in some forms, selective : if tones are sounded in their neighbourhood, certain hairs remain passive, while others — varying with variation of the stimulus — are thrown into violent vibration. In the same way, the hairs of the feathered antennae of the male mosquito vibrate selectively to notes which correspond in pitch to the hum of the female insect. It is tempting, in such cases, to regard the vibratile organ as auditory, and to conclude that the stridulating, rasping and tapping sounds of the invertebrates are heard by others of their kind as they are by ourselves. It must, however, be remembered that sympathetic vibration is a purely mechanical matter : the excitation set up by the moving hairs might release a reflex, or might be sensed as jar or quiver. Indeed, the close relation of the otolith organ to the organ of touch makes it probable that their sensations would be closely alike. Even the fish, in which the membranous labyrinth has begun to divide into a vestibular and a cochlear portion, do not appear to possess sensations of

hearing, while they are extremely sensitive to jar of the water in which they swim. On the whole, then, and with the reserve which is due to the obscurity of the subject, we may say that true hearing probably appears at a point fairly high up in the vertebrate series.

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OTHER ORGANIC SENSATIONS

§ 56. **The Sensitivity of the Abdominal Organs.** — We may group together, under the name of visceral sensations, all the sensations, except those of sex, which are derived from the internal organs of the body below the diaphragm. The evidence for the nature and origin of these sensations, and for the part that they play in the make-up of consciousness, comes from various sources, surgical, physiological, pathological, psychological. It is not all of the same tenor, and no single line is at all complete.

Let us take, first, the testimony of the surgeon. Operations upon the abdominal organs are now fairly common, and in many cases the anaesthetic employed affects only the outer skin and the underlying connective tissue. Under these circumstances, it has been found that stomach, intestine, liver, gall bladder, kidney, — with the investing and interstitial tissues, — as well as the rectal mucous membrane, the anterior wall of the vagina, the uterus, the ovaries, the Fallopian tubes with the adjacent portions of the broad ligaments, and probably the part of the testes that is covered by serous membrane, are one and all insensitive. The organs may be pinched, stretched, cut, pricked, burned, cooled, and the patient knows nothing about it. On the other hand, the external or parietal peritoneum, which lines the abdominal and pelvic walls, the muscular and serous layers of the diaphragm, and the tunica vaginalis, are extremely sensitive: the first and third, apparently,

to pain alone, the second to pressure and pain. From the surgical point of view, then, the whole mass of visceral sensations must be referred to these three tissues. The sense of satiety, of a full stomach, would come from an upward pressure against the diaphragm, colic pains would be due to the pressure or pull of the distended intestine upon the peritoneum, and so on.

On the whole, the results of direct physiological experiment support this conclusion. Nevertheless, physiology seems to take away with the one hand only to give with the other. We learn, for instance, that there are enough sensory mechanisms in the abdominal cavity to furnish any number of sensations. We are reminded, also, of the difference between adequate and inadequate stimuli. The inroads of a surgical operation are not natural or normal to the organism; and it is entirely possible, from the physiological standpoint, that sensations may be aroused, by natural processes, in organs which fail to respond to external attack. In particular, we are confronted with the law of reflex pain. Wherever two regions, of low and high sensitivity respectively, stand in close nervous connection, an injury done to the former is referred, as sensation of pain, to the latter. Now viscera and skin are thus connected. Hence a visceral disturbance might be sensed, locally, as mere vague oppression, while the related area of the skin was the seat of sharp, cutting pain. In other words, the skin may steal from the viscera as taste steals from smell.

If we turn to pathology, we find the facts as definite as those offered by surgery, but of an opposite character. There are cases of visceral anaesthesia, in which the patients cannot tell whether they have eaten enough, but

must measure out the amount of their food; in which they do not feel the need of evacuating the bladder and bowels, etc. Now in these cases there is loss, not only of such things as appetite, nausea, repugnance to food, the sense of renewed vigour after sleep, but also of feeling and of perception. Feeling may be lost entirely; the patients are apathetic, incapable of most if not of all the emotions; the agreeable and the disagreeable aspects of experience disappear together. We return to these phenomena in § 74. More to the present point is the loss of perception. The patients have no knowledge of the flight of time; in the daytime they depend solely upon the clock, and on waking in the morning they are not aware that they have slept. Plainly, then, if we may trust pathology, visceral sensations exist in some variety, and serve as the raw material of certain complex perceptual processes.

All these differences may be reconciled, though as yet only in a broad and general way, by an appeal to psychology. The most obvious thing about visceral sensations is their periodical recurrence. For the greater part of the day we know nothing whatever, if we are in good health, of the state of the abdominal organs; introspection of visceral sensation is impossible, because there is no sensation to introspect. But for short times, at fairly definite intervals, they loom large in consciousness; either as hunger and repletion, thirst and its satisfaction, or as the characteristic feels that precede, accompany and follow urination and defaecation. It is, evidently, this character of recurrence that fits them for the part they play in perception. It proves, further, that they are aroused only under certain peculiar circumstances, on the occurrence of certain changes in their organs. Since surgical operations

do not reproduce these circumstances or bring about these changes, it is not surprising that the organs should show themselves insensitive to knife and cautery. The negative results are facts, but from the standpoint of psychology they are irrelevant facts. The same thing holds of the results of physiological experiment. The physiologist asserts that the stomach is insensitive to temperature; if we drink hot or ice-cold water, we have at most a dull heaviness in the stomach, while the warmth or cold is referred by introspection to the body wall. But there may be a law of reflex temperature sensation, as there is a law of reflex pain. And in any case, we have no proof, in such results, that the stomach is altogether insensitive, when stimulated adequately, in the appropriate way.

In general, then, we may say that the external peritoneum is probably responsible for colic pains; that the diaphragm furnishes both muscular sensation and pain; and that there are other sensations, peculiar to the alimentary canal, which are aroused by special stimuli at recurring intervals of time. We have now to examine these latter in more detail.

We distinguish, in ordinary speech, many different sorts of pain: we speak of head-ache, tooth-ache, stomach-ache, ear-ache; of rheumatic, sciatic, gouty, neuralgic, anginal, labour pains; and, more generally, of dull, acute, fine, massive, throbbing, lancing, gnawing, cutting, aching, boring, shooting, stabbing, rending, chafing, smarting, burning, scalding, racking pains. It is a disputed question whether pain, as used in these phrases, is like colour a general name for a number of sensible qualities, or like cold the name of a single quality. On the whole, it seems necessary to distinguish two ultimate pain sensations, a fine bright and a heavy dull pain (§ 41); all other differences, however, appear to be reducible to differences of intensity, of diffusion, and of duration or periodicity.

Thus, a stabbing pain is a pain of limited area, definitely localised, which suddenly attains a high degree of intensity; a boring pain oscillates between certain limits of intensity; a racking pain swells gradually to its maximum, and then sinks again; and so on.

§ 57. **The Sensations of the Digestive and Urinary Systems.** — Thirst is localised in the soft palate, and appears as a diffuse pressure or as a blend of pressure and warmth, — dryness and feverishness. It may be quenched, for a time, by painting the soft palate with acid, or by rinsing the mouth with water, or even by wetting the skin of face and neck: that is to say, by stimuli which cool and moisten the tissues, and start the salivary glands to action. It soon recurs, however, as what Helmholtz called a general feel of the lack of water in the body, though it is still referred predominantly to the soft palate; in this form, it may be assuaged by the injection of fluid into a vein. We may, perhaps, suppose that a deficiency of lymph in the lymph-spaces of the mucosa of the soft palate brings about a relaxation of the membrane, which serves to stimulate Pacinian or kindred organs. Since the alimentary canal is the normal channel by which the body is supplied with water, it is natural that a regulative organ of especial sensitiveness should be placed at its entrance.

Next in order, if we travel from above downwards, is the sensation of hard pressure that results from the hasty swallowing of too large a morsel or too large a gulp of liquid. Unlike most of the alimentary sensations, this pressure is localised towards the back. Its downward course can be followed by introspection. It often has upon it a suggestion of nausea, and undoubtedly comes from the oesophagus; but whether from the free nerve-endings of the mucosa or from the layers of striped muscle, we do not know.

Nausea itself is usually preceded and accompanied by cold sweat and copious salivation. Besides the sensations thus arising, it is sometimes complicated by a bitter taste at the back of the mouth, by sensations of taste and smell from contents returned by the stomach, and by dizziness. Intrinsically, it appears as a sensation of pressure-like quality, localised at the lower end of the oesophagus, and probably due to muscular constriction. — The act of vomiting introduces sensations from the muscles of the abdominal wall and the diaphragm, and from the pharynx, all of familiar quality.

Hunger, like nausea, is a complex experience. It is characterised by a dull ache, extending throughout the lower jaw; by pressure in the pharynx; and by the sensations accompanying salivation. Its specific sensation is a dull pressure in the stomach; this rises, through a gnawing soreness, to positive aching pain. The reference of hunger to the stomach is as unhesitating as that of thirst to the soft palate, and its localisation may be made definite by palpation of the skin. The sensation may, perhaps, be ascribed to tension of the stomach, caused by the engorgement of the mucosa with the digestive granules developed in the cells. — The sense of repletion, and the oppression of a too hearty meal, are also referred to the stomach, and may be definitely localised by palpation. We can only guess that they are due to a tension of the walls of the stomach, possibly complicated, in the case of overloading, by pressure upon the abdominal wall and the diaphragm.

The intestinal tract from stomach to rectum is usually free from sensation, with the exception of occasional colic pain. Persons with weak digestion, however, report that they generally find, after eating, stationary or travelling

pressure sensations in this region. The sensations are referred to the front of the body, and may be localised by palpation.

The sensations which appear before, during, and after defaecation are those of pressure and dull pain. In urination, the sensation of warmth is added. The pressure in both cases is somewhat sore, tinged with an ache; it is not unlike the sore muscular sensation (§ 45). The relief that follows evacuation is partly a negative matter; we are freed from a mass of insistent sensation and can turn our attention elsewhere. Oftentimes, however, we get a positive sense of lightness, akin to the bright diffused pressures of health and excitement (§ 46) and perhaps referable to the same organs.

It is tempting to regard the specific sensations of thirst, nausea, hunger, etc., as novel qualities. Closely analysed, however, all the experiences above described seem to reduce to two familiar continua: the light, thrilling sensations which pass into dull, hard pressure, and the sore, achy sensations which pass into dull pain. It would be overhasty to assert that the pressure quality in hunger and nausea, for instance, is precisely the same; but, at any rate, analysis reveals a likeness which is surprising in view of the gross difference between the hungry and the nauseated consciousness. This perceptual difference will occupy us later (Pt. ii.), as will also the question of internal localisation.

§ 58. **The Sensations of the Circulatory and Respiratory Systems.** — For the most part, the action of heart and lungs is not accompanied by sensation. There are times, however, — after severe exertion, or during transient disturbance of function, — when the separate heart-beats are clearly sensed as a dull throbbing pressure: it is not easy to say whether the sensations are localised in the body

wall or in the heart itself. Further, when we are anxious or worried or apprehensive, we get a characteristic sense of oppression from the cardiac region. This may appear alone, or in connection with nausea or choking sensations of muscular pressure from the pharynx. The two latter experiences are so well-marked that they have received names in everyday speech; in the first case, we say that we have a sinking of the stomach, in the latter that the heart has come up to the mouth.

Again, it is supposed that circulatory sensations, due to the contraction of the walls of the blood-vessels, play a part in the experiences of shudder, shiver, and goose-flesh. Analysis is here very difficult. In shuddering, however, there is certainly a muscular element; in shivering, this is complicated by sensations of cold; and in goose-flesh we have, perhaps, besides pressure from the hair-bulbs, sensations from the contraction of the unstriped muscles. The tingling sensations that occur when circulation is suddenly restored to a benumbed limb — pins and needles, as they are called — are also, in all probability, to be ascribed to nerve-endings in the walls of the vessels.

A sense of oppression, not unlike that which comes from the cardiac region and often associated to it, appears in the chest in connection with disturbances of breathing. It may be induced by a cramped position of the body, as when one sits for a long time bent over a desk; or by bad air, as in a lecture or concert room; or by an unusual effort of respiration, as in the first stages of running, before the respiratory mechanism has become adapted and the runner, as we say, has got his second wind. At low intensities we speak of it as stuffiness; at the highest, as suffocation; when it is fused with cardiac oppression, as dis-

tress. It is probably to be referred to nerve-endings in the alveoli of the lungs, and is prominent in asthma and other dyspnoeic conditions. The bracing sense of fresh air, on the other hand, is due to sensations from the respiratory muscles.

§ 59. **The Sensations of the Genital System.** — Reproduction is one of the supreme vital functions; and the study of the reproductive organs, their development and mechanism, belongs accordingly to all divisions of the science of life, — to biology in the narrower sense, to comparative anatomy, to embryology and histology, and to physiology. These sciences have, as a matter of fact, devoted much attention to the various phases of the problem; they have ascertained facts, established laws, and worked out homologies and correlations. Especial interest has been taken, of recent years, in the questions of sexual pathology, not only in their medical, but also in their moral, social and legal aspects. It is the more surprising, then, that very little is known, psychologically, of sexual sensation.

There seems to be no doubt that all the reproductive functions may run their course reflexly, without any sort of conscious concomitant. Normally, however, the train of reflexes is under cerebral control. Sexual stimulation implies, besides sensations from the sex-organs themselves, a wide-spread arousal of other organic sensations, and a play of perceptions and ideas, visual, tactual and kinaesthetic. The special sensations of the genital system appear to occur in three stages: first as an irritation or excitement, which accompanies the tumescence of certain erectile tissues; then as sexual gratification, which culminates in the orgasm accompanying ejaculation or the consummation of the sexual act; and thirdly as relief, the sexual analepsis which follows coition.

Sexual excitement, so far as it is a matter of specific sensation, is usually described as a need of evacuation. Thus, Bain writes that "the appetite that brings the sexes together is founded on peculiar secretions which periodically accumulate within the system, producing a feeling of oppression until they are either discharged or absorbed."[1] This view, however, is negatived by many lines of evidence. Sexual appetite and its satisfaction may persist after excision of the testes in the male and the ovaries, Fallopian tubes and uterus in the female; in children there frequently exists a well-defined sexual excitement long before there is any true sexual secretion; in adults the sensations may continue to appear long after the sexual glands have discontinued their functions; and, finally, there may be an intensive sexual life in the congenital absence of any sexual glands at all. Moreover, sexual irritability is localised, in the male on the surface of the glans penis, and in the female in the clitoris and the adjacent erectile parts. These organs are sexually sensitive even in the flaccid state, though the degree of sensitivity differs greatly in different individuals and even for the same individual at different times. Both in quality and in its irradiating character the sensation of sexual excitement resembles tickling. We do not know how it is aroused: there are no lust spots, akin to the sensitive spots of the skin, and the organs sometimes described as genital corpuscles are certainly not sexual in function.

Most authorities appear to regard the orgastic sensations, in both sexes, as distinct and unique. It is, however, as difficult in their case as it is in those of hunger and nausea to say whether we are in presence of a novel quality or simply of a specific resultant of muscular and glandular activity. Since the sensations may appear after extirpation of testes and ovaries, the latter view would seem to be the more probable.

Sexual analepsis is made up, for the most part, of muscular sensations. It is a general sense, either of lightness and relief, or of lassitude and faintness, very like that which follows urination and defaecation: indeed, we may suppose that this resemblance is

[1] A. Bain, *The Senses and the Intellect*, 1868, 244.

mainly responsible for the evacuation theory of sexual sensation at large.

The sensations attending menstruation and parturition are those of muscular pressure, pain and strain, and sometimes of nausea; neither among them nor in the following analeptic states are new qualities found.

References for Further Reading

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SYNAESTHESIA

§ 60. **Synaesthesia.** — Every sensory stimulus of moderate intensity arouses a wide-spread reaction. It has been shown, for instance, that the sounding of a single note upon the harmonium will not only bring about an adjustment of the organs of hearing, but will also call out visual, verbal and other associations, often of considerable vividness and detail, as well as organic sets and attitudes of various kinds. Such a result is, perhaps, only natural, in view of the manifold connections within the nervous system, — though it comes as something of a surprise to those who are accustomed to look only at the local effects of stimulation.

Quite apart, however, from this general disturbance of the organism, it not infrequently happens that a stimulus sets up, besides its appropriate sensation, a secondary or concomitant sensation. The phenomena of synaesthesia, as it is called, are scattered over the whole range of sensation, and are extremely varied in nature. Sometimes they seem to depend upon a purely individual feature of nervous constitution, as when a sour taste makes the scalp itch; sometimes they are common to a large number of persons: most of us shudder and grit the teeth when we hear the squeak of chalk against the blackboard, or the grating sound of a saw upon metal. The connection may obtain between separate sense-departments, as sound and sight, or between different areas of a single sense-department; thus, an itching of the nose often comes along with

pricking sensations at the back of the neck on the same side, and the emptying of bladder or rectum is accompanied by a muscular shiver. In some cases, the concomitance is stable, in others it is highly variable; in some it is limited, as it were incidental, in others systematic, extending to an entire series of qualities.

The commonest form of systematic synaesthesia, known as coloured hearing, occurs almost as frequently as partial colour-blindness. In it, any auditory stimulus, noise, tone or sound complex, may arouse a photism or chromatism, a visual image of light or colour. No general rules can be laid down, since the associations vary for different persons and, within limits, may vary for the same person at different times. Two types, however, have been distinguished. In the one, the connection is direct; the sound calls up the sight without any intermediary; in the other it is indirect, by way of organic sensations.

The following case may be quoted in illustration. "The vowels of the English language always appear to me, when I think of them, as possessing certain colours. Consonants, when thought of by themselves, are of a purplish black; but when I think of a whole word, the colour of the consonants tends towards the colour of the vowels. For example, in the word 'Tuesday,' when I think of each letter separately, the consonants are purplish-black, *u* is a light dove colour, *e* is a pale emerald green, and *a* is yellow; but when I think of the whole word together, the first part is a light grey-green, and the latter part yellow. Each word is a distinct whole. I have always associated the same colours with the same letters, and no effort will change the colour of one letter, transferring it to another."[1]

In rare cases, colours accompany the sensations of taste and

[1] From a letter cited by F. Galton, *Inquiries into Human Faculty and its Development*, 1883, 149.

smell. Salt, for instance, is given by one observer as dull red, bitter as brown, sour as green or greenish blue, and sweet as a clear, bright blue. Colour concomitants of pain, pressure and temperature have also been recorded: thus, the plunging of the hands into cold water may be seen as bright red.

The synaesthetically aroused colours do not follow the lines of what we should suppose to be the least associative resistance. It is odd to read that "the word 'red' assumes a light-green tint, while the word 'yellow' is light-green at the beginning and red at the end." And while the observer just mentioned sees the taste of meat as red and brown, and that of bananas as yellow, he tastes Graham bread as a rich red, and all ice creams — except chocolate and coffee, which are brown because they have a bitter component — as blue.

Tonal vision, the systematic opposite of coloured hearing, seems not to occur. Incidental colour-phonisms have, however, been noted: in one case all the blues, bright as well as dark, are heard as deep and dull, and all the yellows as more or less high and ringing tones. Phonisms of pain, pressure and temperature are also known to exist. Recently, a case of gustatory (or rather gustatory-tactual) audition has been discovered; the sound of 'intelligence,' for example, tastes like raw sliced tomato, and the sound of 'interest' like stewed tomato!

It is clear that we cannot explain coloured hearing as we explain the shudder set up by a shrill or grating noise. The colours are presented to the mind's eye; they are, as we have said, images, not peripherally excited sensations. Nevertheless, several lines of evidence go to show that they belong to the domain of sensation rather than to that of the association of ideas. First, the concomitance of colour-image and sound is, in many cases, far too detailed and too persistent to be referred to association, in the ordinary sense of that word. It is impossible that the connections should have been established during childhood; it

is impossible, had they been thus established, that they should continue unchanged. Further, attempts have been made, by trained and interested observers, to trace back their synaesthetic experiences to associations formed in childhood; but in spite of all efforts they have ended in failure. Again, we should expect that an association due to experience would show, along with a certain measure of variation, an underlying agreement or correspondence; whereas, as Galton remarks, "no two people agree, or hardly ever do so, as to the colour they associate with the same sound." And lastly, coloured hearing is an hereditary trait; it tends strongly to run in families. While, then, it is possible, and even probable, that synaesthesia of the incidental type may be the legacy of some vivid or thrilling experience in early life, we are forced to the conclusion that, in general, it represents a congenital endowment. As to its physical basis, we can merely guess. It may depend upon some abnormal disposition of the paths of connection within the brain. Or possibly it may depend, as a recent writer has suggested, upon an unusual elasticity of the walls of the cerebral arteries. On this view, a rush of blood to the auditory centre might, owing to the extensibility of the arteries, be propagated to the visual centre; the hearing would be coloured. The theory accounts for the loss or reduction of synaesthesia as we pass from childhood to mature life, and for its occurrence in moments of emotional stress. As the arterial structure might be a matter either of inheritance or of individual peculiarity, it allows further for both the congenital and the acquired types of synaesthesia.

§ 61. **The Image.** — The facts of synaesthesia lead up to the question of the nature of the image, and of its dif-

ferences from sensation. It is usually said that the image differs from the corresponding sensation in three respects: its qualities are relatively pale, faded, washed out, misty; and its intensity and duration are markedly less.

Since these differences are all differences of degree, and not of kind, it should be possible to find experimental conditions under which the sensation and the image are confused. Experiments have, in fact, been made, and with positive result, in the fields of sight, sound and touch.

If, for instance, the observer is seated in a well-lighted room facing a sheet of ground glass, behind which is a screened projection lantern, it is often impossible for him to decide whether the faint colours that he sees on the glass are due to the lantern or to his own imagination. You say to him: Imagine that there is a picture of a banana on the glass! — and in many cases it makes no difference at all whether you show a strip of very faint yellow light from the lantern or whether you shut off the objective light altogether. The strip of seen yellow is confused with a yellow image. The experimenter, who regulates the course of the observations by signalling to a third person when the lantern is to be turned on, is sometimes greatly surprised at the gross errors made by the observer. What seems to him obviously sensory may be reported, without hesitation, as imaginative.

Again, we are frequently in doubt, in everyday life, whether we hear a particular sound or merely imagine it. And if, in the laboratory, the observer is required to listen intently to a continuous faint noise, such as is produced by the falling of a stream of fine sand (§ 81), the same confusion will be noted. The experimenter may reduce the stream to a mere trickle, and may finally stop it; the observer will still, in many cases, believe that he hears the hiss.

Lastly, a similar confusion is found in experiments upon pressure and tickling. If, for example, in the course of a series of stimulations of a pressure spot, the experimenter says Now! but

omits to touch the skin, the observer may, nevertheless, report the arousal of a pressure sensation.

It has been found, further, that a visually minded observer, who knows nothing of the laws of the negative after-image, may describe — and describe in correct terms — the after-images of merely imagined colours. It is also a matter of common knowledge that, in certain pathological states, the image may become what is called an hallucination, that is, may take on all the characters of clear and intensive sensation.

How is it, then, that we so rarely confuse image with sensation in our everyday experience? Well, the confusion may not be so uncommon as we suppose. However, if it is, the distinction may be accounted for, at any rate in large measure, by the differences of conscious context or setting in which the two processes appear. Images, for instance, seem to be less sharply localised than sensations; they change and shift more rapidly, and in a meaningless way; they move with movement of the eyes. But the writer is not sure that the image does not, as a rule, evince a sort of textural difference from sensation; that it is not more filmy, more transparent, more vaporous. If this is the case, then it is better to consider sensation and image as sub-classes of a particular type of mental element than to include them outright in a single class (§ 10).

Individual minds differ widely in the nature and frequency of their characteristic image-processes. Visual and auditory images are of common occurrence, although the auditory image appears, in general, to be connected with actual innervation of the larynx, that is, with kinaesthesis. Kinaesthetic images are extremely difficult to distinguish from kinaesthetic sensations. The difference, in the writer's experience, is largely a matter of complexity:

the mental nod which gives assent to an argument is more schematic, involves fewer muscles and involves them less solidly, than an actual nod. Images of taste and smell have often been reported, but only exceptionally play any considerable part in consciousness. Organic images are rare.

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THE INTENSITY OF SENSATION

§ 62. **The Intensity of Sensation.** — All sensations have the attribute of intensity. A light may be bright or dull, a tone loud or faint, a pressure heavy or light, a taste strong or weak. If we take any given sensation as a starting point, we can travel from it in a straight line either towards zero, the point of its disappearance, or towards a maximum, the point of its greatest possible strength (§ 12).

The intensities that lie in order along this line are, in their way, as individual as are the qualities that lie, for instance, along any straight line of the colour pyramid. A loud tone is not a sum of two or three weak tones, but something entirely different from a weak tone. It may be reduced to a weak tone, if we move from high to low upon the intensive scale, just as a red may be reduced to pink if we move from red towards white; but it no more contains a number of weak tones than pink contains white. In other words, intensity of sensation must not be confused with intensity of stimulus. If we want to use a weight of 5 cg. in a balance, it makes no difference whether we take a single weight of 5 cg., or two of 2 and one of 1 cg., or five of 1 cg. If we want a light of 16 c. p. at a corner of a room, it makes no difference whether we take a single 16 c. p. bulb, or two of 8, or four of 4 c. p. Stimuli can be added, subtracted, multiplied; the greater, stronger stimulus contains or sums up a certain number of lesser, weaker stimuli of the same kind. It is otherwise with sensation.

You cannot get the heavy by adding together, mentally, a number of light, or the bright by adding together a number of dull: you cannot say that the heavy differs from the light by a certain fraction of the heavy or multiple of the light, or the bright from the dull by a certain fraction of the bright or multiple of the dull. Every intensity of sensation is itself, individual and characteristic: the intensive sensations represent, as we have said, points or positions upon an intensive scale which runs from a lower limiting value to a maximum, just precisely as a particular pink or olive represents a point within or upon the colour pyramid.

We live so habitually in a world of objects, and we think so habitually in terms of common sense, that it is difficult for us to take up the psychological standpoint towards intensity of sensation, and to look at consciousness as it is, apart from any objective reference. This book, we say, is heavier than that; this lamp gives the better illumination of the two; this piano has a louder tone than the others. Strictly interpreted, such statements may mean either one of two things. They may be taken physically, to mean that the books weigh differently in the balance, the lamps measure differently in c. p., the piano strings set up air-waves of different amplitude; or they may be taken psychologically, to mean that the books feel heavy and light, the lamps look bright and dull, the piano tones sound louder and less loud. As a rule, however, we are talking neither physics nor psychology, but a confused mixture of the two. It is true, of course, that we gauge the weight by lifting, the illumination by eye, and the strength of tone by ear. But, in doing this, we transfer to sensation the properties that really belong to stimulus: we think of the 'feel' of the heavier book as the 'feel' of the lighter with some more 'feel' added to it; we take the look of the bright lamp to be the same thing as the look of the dull, only with an addition; we regard the sound of the loud instrument as identical with the sound of the weaker, only that there is more

of it. In other words, we make the intensive sensation a copy of the intensive stimulus, and we assume that the strong sensation is built up by adding to the weak, and the weak produced by subtracting from the strong.

This fallacy of common sense is easily exposed by experiment. Take two glasses of sugared water, the one moderately sweet, the other very sweet, syrupy. Taste them in turn. Introspection declares at once that the tastes lie in the same straight line; the sweets are intensive variations of the same quality. But there is no hint — if you think only of the tastes themselves, and forget about the sugar — that the strong sweet contains the weak, is the sum of a number of weak. And it is impossible to imagine a third sweet which, if added to the weak, shall give the strong: the adding of sensation to sensation is meaningless, a task that you cannot lay hold of. The strong sweet lies fairly high up, the moderate sweet somewhat lower down, on the scale of sweet intensities. That is all.

Let us carry the experiment a little farther. Take, besides the two cups of sugared water, which we will call *a* and *b*, a number of others; make them all different, but let them all be sweeter than the moderately sweet *a* and less sweet than the syrupy *b*. Set the cups out upon a table, *a* and *b* to your left and right respectively, and the rest grouped at haphazard in the middle. Now try to pick out, by taste, a sweet *c* which lies for sensation midway between *a* and *b*: taste first *a*, then a cup from the middle group, and then *b*; and keep on tasting until you are satisfied. If you take your time, and rinse the mouth between observations, so that the tongue is not cloyed, the task is rather surprisingly easy, — and the result is illuminating. For it means that we can measure off distances along the straight line which includes all the intensities of sweet; we can say by taste that the distance *ac* is equal to the distance *cb*, precisely as we can judge by eye that two spaces between the pictures on the wall are equal. Nothing could show more clearly that the intensive sensation is simply a point or position upon an intensive scale; and no experience could refute more decisively the common-sense notion that it is a copy of the intensive stimulus.

Within wide limits, the intensity of sensation may be treated as an independent variable: that is to say, we may discuss it without regard to quality, and may assume that it varies while quality remains unchanged. Nevertheless, it is important that the limits be recognised. We find, on the one hand, qualities that are intrinsically weak or strong; and we find, on the other hand, intensities that are bound up with definite qualities. In these cases, the two attributes must be considered together.

We noted in § 24 that high tones are intrinsically loud and low tones intrinsically weak. The lowest tones remain faint, even when the energy of stimulus is, relatively, very considerable; and high tones give the impression of loudness, even when their stimuli are little more than liminal. So, in the sense of taste, bitter is an intrinsically strong sensation, as compared with sour, sweet and salt. Conversely, there are many scents (violet, tea, vanilla) that are intrinsically weak: they are easy to detect, they are insistent (§ 12), but they are never strong as asafoetida or musk is strong.

Again, we have seen that intensive variation of punctiform pressure stimulus gives the qualitative series contact, pressure, granular pressure (§ 39), and of punctiform pain stimulus the series itch, prick, pain (§ 41); while the dragging sensation from the muscles and the sensation of tendinous strain both alike pass over, at high intensities, into dull pain (§§ 45, 46). The most striking instance of the connection of particular intensities with definite qualities is, however, afforded by visual sensation. A change in the intensity of visual stimulus not only renders the sensation brighter or duller (intensity), but also makes it lighter or darker (quality), and in the case of colour may change all three of the constituent attributes, hue, tint and chroma (§ 16). Some psychologists have argued from this that visual sensations do not possess the attribute of intensity at all; that brightness and lightness, dullness and darkness are simply different

names for the same qualitative characters.[1] Such a conclusion is, however, neither probable in itself nor supported by visual theory.

We saw in § 22 that the retinal processes which arouse the sensations of *Bk* and *W* are antagonistic and incompatible. If, then, a *Bk* and a *W* fall at the same time upon the same area of the retina, any one of three things may happen: the resulting processes may be equal in intensity as well as opposite in direction, and the retina may be undisturbed; or the *Bk* may be the stronger stimulus, and may set up a *Bk*-process of the intensity of $Bk - W$; or the *W* may be the stronger stimulus, and may set up a *W*-process of the intensity $W - Bk$. In other words, a purely retinal vision would give us various intensities of *Bk* and *W*, but no sensations of grey. These relations are, however, complicated by the existence of the sensation of neutral grey, a cortical sensation of constant quality; and it is the addition of neutral grey to the retinal intensities of *Bk* and *W* that makes every change in the black-white series, as we actually have it, a change of quality as well as of intensity. A retinal *Bk*, of whatever intensity, must darken the cortical grey; a retinal *W* must lighten it: and darkening and lightening are shifts of quality. To secure intensive variation, with constancy of quality, we should have to increase the energy of the *Bk* and *W* components of the cortical grey, both together, in equal measure; but this is the very thing that the constitution of the retina forbids.[2] — In fine, then, intensity is an

[1] F. Hillebrand, *Ueber die specifische Helligkeit der Farben*, in *Sitzungsberichte der kais. Akademie der Wissenchaften in Wien, Mathem.-naturw. Classe*, xcviii., Abth. iii., February, 1889, 88 f.; O. Kuelpe, *Outlines of Psychology*, 1909, 114.

[2] This explanation is due to G. E. Mueller: see *Zur Psychophysik der Gesichtsempfindungen*, in *Zeitschrift f. Psychologie u. Physiologie d. Sinnesorgane*, x., 1896, 31 ff.; xiv., 1897, 60 ff. —

We have to solve this problem of intensity for our own visual system; and our visual system is based upon the principle of antagonism. But it is quite possible that other eyes are built upon a different plan. It is possible, for instance, to think of a primitive eye, whose sensations should one and all be sensations of light (as opposed to sensations of dark) and should show a

attribute of visual as it is of all other sensations; only, the dual nature, peripheral and central, of the visual apparatus brings it about that intensive change of a sensation of light necessarily involves transition to another quality. When this fact is taken into account along with the facts of § 16, the qualitative changes due to change of intensity in the sphere of colour (hue, tint and chroma) follow of themselves. —

So far, we have been considering cases in which the attributes of quality and intensity are interdependent. There are, further, many instances in which we cannot vary intensity without change of quality, merely because we cannot control the stimuli. For instance, it is impossible, except in the higher regions of the tonal scale, to produce a sensibly simple tone that is at all loud. If we take a flue pipe or a bottle, we find that increase of air-pressure sends the tone up; if we take a tuning-fork, we find that a violent blow introduces complicating noises and overtones. Again, nothing might seem easier than to secure a graded series of intensities of noise; all that we have to do is to let a ball drop from different heights upon a wooden plate. Experiment shows, however, that change in the height of fall is very likely to bring with it a change in the pitch, as well as in the loudness of the noise; it is, as a matter of fact, difficult to maintain a constant quality of noise even within the comparatively short range of intensities required for laboratory work. Once more, the quality of what we have called resultant odours (§ 32) seldom remains stable over any wide extent of the intensive scale. It seems that the component stimuli behave differently, gain or lose in power to make themselves sensed, at different intensities; though in a field where so little is known it is hazardous to risk an explanation.

regular intensive gradation. The world in which an organism possessed of such an eye would live might then be very light, light, moderately light, hardly light, or not light: the sensations of light would range between a maximal and a zero intensity, precisely as our own sensations of noise range between maximal loudness and silence, — that is, no noise at all. The organism would not distinguish, as we do, between light and dark, but would simply experience varying degrees of light. In the absence of an adequate light stimulus it would not, as we do, see dark, but would see nothing. Cf. § 15.

§ 63. **Mental Measurement.** — The psychological problem of the intensity of sensation is bound up, historically, with a much wider question, the question of the possibility of mental measurement. Every science tries to state its facts and to formulate its laws as precisely as possible, that is, in quantitative terms, in measured amounts. Thus, it is not enough to say that gravitation is a force which the earth exerts upon every particle of matter; it is not even enough to say that the force is proportional to the mass of the material body, but independent of the particular kind of matter of which it is composed: the physicist goes further, and measures the force of gravitation in terms of acceleration. Physics and chemistry are, indeed, from end to end, quantitative or measuring sciences. But biology, too, tries to measure: the modern biologist measures the range of variation shown by the members of a species, gives numerical expression to the factors that determine heredity, and so on. And psychology has to face the same issue. There are facts of mind and there are laws of mind: can, then, these facts and laws be quantified? can we measure mind? Now the question of the possibility of mental measurement has been chiefly discussed, as was said above, with reference to the intensity of sensation. Here, therefore, is the fitting place to take it up. We shall ask what measurement means; we shall ask in what sense, and to what extent, measurement may be applied in psychology; and we shall draw our illustrations from the study of sense-intensity, as defined in the preceding § 62. —

Whenever we measure, in any department of science, we compare a given magnitude with some conventional unit of the same kind, and determine how many times the unit is contained in the magnitude. If we say, for instance, that

a certain line is 5 cm. long, we mean that we have compared the line with the conventional unit of length, 1 cm., and have found that it contains this unit five times over. All measurement thus implies three given terms : the two limiting points of the magnitude to be measured (beginning and end, top and bottom, extreme right and extreme left, zero and maximum), and a third point lying at unit-distance from the one or the other limiting point.

The intensities of sensation lie, as we have said, along a straight line which extends from a zero-point to a point of maximal strength. Here is a magnitude with limiting points. In order to measure sense-intensity, — the intensity of sensations of light or tone or noise, of pressure or taste or smell, — we have, first, to establish these two points, definitely and accurately, and secondly to determine the unit of intensive measurement, the standard subdivision of the total line.

It is important to realise that the unit of measurement is always a conventional unit ; its choice is simply a matter of practical convenience. Scientific men are now generally agreed that the unit of physical space shall be the cm., the unit of time the sec., and the unit of mass the gr. There is, however, nothing absolute about these units. The metric system makes calculation easy, relates the three fundamental quantities in a very simple manner ; but that is its sole, as it is its sufficient, claim to acceptance.

And just as the unit of measurement is conventional, and the pace or the span, the ounce or the pound, will give us perfectly valid measures of space and mass, so also may our selection of the magnitude to be measured be arbitrary or conventional. The ordinary postal balance weighs up to 16 oz. ; the ordinary kitchen scales weigh up to 4 lb. We can measure — we can express by the number of contained units from zero to maximum — any magnitude that chance throws in our way.

But this means that our experiments with the cups of sugared

water (§ 62) was a quantitative experiment, a measurement of mind. We had, as our arbitrarily chosen magnitude, the sense-distance from the moderately sweet *a* to the syrupy *b*. Then we bisected that distance, by finding the sweet *c* that lay midway for sensation between *a* and *b*. The half-distance was our arbitrary unit; and we can write, in terms of it, $ab = 2\,ac = 2\,cb$, just as with a unit of 1 ft. we can say that the regular carpenter's rule contains 2 ft. The three points by help of which we have measured, the two limiting points *a*, *b* upon the intensive line of sweets and the point *c* which lies at unit-distance from the lower point *a*, can be established, for comparative purposes, by a statement of the relative amounts of sugar and water in the three solutions.

We may take another illustration of the same thing. Let the horizontal line in Fig. 25 represent the complete scale of sensation intensity in the sphere of noise. And suppose that we have given the two noises *m* and *o*, a weaker and a stronger noise due, perhaps, to the falling of two ivory balls from different heights upon ebony plates. By selecting from a number of intermediate noises, we may determine the noise *n* that lies midway for sensation between *m* and *o*. We may then write $mo = 2\,mn = 2\,no$. That established, we can take the distance *no* as given, and can compare *no* with distances above *o*, until we finally reach a point *p* such that $no = op$. We may then write $mp = 3\,mn$. Again, we can take *mn* as given, and compare it with distances below *m*, until we reach the point *l* at which $lm = mn$. We may then write $lp = 4\,lm$. And we can evidently go on to determine *q*, *r*, . . . and *k*, *j*, . . . in the same manner. So that, if we continue the procedure as far as possible towards the limits of the horizontal line of the Fig., we shall finally have measured the entire range of noise-intensities in terms of an arbitrary unit. Between the limits of the faintest and the loudest noise there will be so-and-so many steps, or distances, of the unit-magnitude *mn*. This is measurement of mind. —

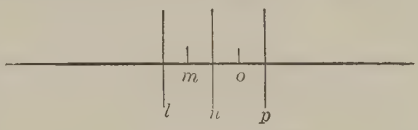


FIG. 25.

In neither of the above instances, however, has the measurement

been methodical. We took any sweet-distance *ab*, and any noise-distance *mo*. It would have been more methodical to determine, at the outset, the two end-points of the total line of sweets and noises, to determine what are called the liminal and the terminal intensities of sweet-sensation and noise-sensation. Moreover, we took as our units of measurement $\frac{ab}{2}$ and $\frac{mo}{2}$. Now we do not know, in the first place, whether or not these units fit the scale, whether they will divide it up without remainder. And, in the second place, we have no reason to think that other psychologists will adopt them: they do not recommend themselves, in any way, for general use, as comparable with the *c.g.s.* units of the physical sciences.

§ 64. **Liminal and Terminal Stimuli.** — The sense-organ, like any other mechanism, has a certain inertia, offers a certain amount of frictional resistance to stimulus; and has also a definite capacity, transmits so much energy and no more. Hence in all of the sense-departments there are stimuli that are too weak to be sensed, and in all there comes a point beyond which we cannot increase the intensity of sensation by any further increase of stimulus, but get the same response, over and over again, until the organ breaks down.

Instances of subliminal stimuli are not far to seek. Some lights are too faint to be seen: there are stars that, even on the darkest night, remain invisible to the naked eye. Some sounds are too weak to be heard: we know that the clock in the tower is ticking, because we see the hands move; but we have to climb the stairs to hear it. Some pressures are too slight to be felt: we have no knowledge, from the skin, of the flake of cigar-ash that has fallen upon our hand: and so on.

Maximal stimuli fall less commonly within the range of our experience. It is, however, easy to assure oneself that there is a point beyond which sugar cannot further sweeten or quinine make more bitter, and that a continued increase of pressure, after it has carried

the sensation of pressure to a certain height, is felt not as pressure but as pain. Dazzling lights and deafening noises set a like limit to the functional capacity of eye and ear.

The magnitude of stimulus which evokes the sensation at the lower end of the intensive scale, the first term of an intensive series, is known technically as the liminal stimulus. It may be determined as the stimulus which gives a positive result, evokes a sensation, in one-half of a long series of observations, while in the remaining one-half the result is negative or doubtful. This value, so the mathematicians tell us, is as nearly as possible identical with the magnitude of stimulus which, if all sources of error were completely eliminated, would call forth a barely perceptible sensation. Since, however, the liminal stimulus is not a constant but a variable, it cannot in strictness be represented by any single value, not even by the most probable value; its formula must always be written $x \pm y$, where x is the most probable value of the stimulus and $\pm y$ indicates its range of variation.

The magnitude of stimulus which evokes the sensation at the upper end of the intensive scale, the last term of an intensive series, is known technically as the terminal stimulus. Theoretically, it may be determined in the same way; in practice it is rarely approached, out of regard for the integrity of the organ.

A variable quantity is a quantity which varies with change of the conditions under which an observation is made. Thus, a measurement in physics may vary with temperature, with humidity, with stress, as well as with the delicacy of graduation of the measuring instrument. The experimenter seeks, so far as possible, to keep all the conditions constant while a measurement is in progress; but even so there will be a slight range of variation. And the

result is always stated in a qualified way, with reference to the conditions.[1]

The liminal stimulus is, in this sense, a variable; and its variation is due partly to the sense-organ and partly to the brain. When we are tired, for instance, our sense-organs are dulled and our general disposition is unfavourable to close work; the liminal stimulus is, accordingly, much larger than it is when we are fresh. But even under the best conditions there is fluctuation. The organic mechanism, made up of sense-organ and brain, is extraordinarily complicated, and complex machinery gets out of order more easily than simple. Besides, the organic mechanism is plastic, not rigid; it is influenced by all sorts of things, — directly by nutritive factors, indirectly by the state of all the rest of the organism. The wonder is, indeed, not that the liminal stimulus should be a variable quantity, but that it should be so nearly constant, for normal persons, as in fact it turns out to be.

The exact determination of the liminal stimulus, that is, of the amount of mechanical energy required to arouse a sense-organ to response, is a very delicate and difficult matter, and a knowledge of methods and results is of interest only to the special student. It must suffice here to say that, for most of the organs, the measurement has been made.[2] In ordinary laboratory practice it is enough to take a rough determination in empirical terms. Thus,

[1] If there is anything constant in the world, it would seem to be the length of the standard metre, which is the unit of reference for all linear measurement in physics. Yet we are told that "from the result of many years of comparison at the Bureau International [in Paris], the conclusion is reached that the length of a standard can be absolutely guaranteed to an exactitude of about 0.2 micron at all usual temperatures" (W. Hallock and H. T. Wade, *Outlines of the Evolution of Weights and Measures and the Metric System*, 1906, 256). In this statement, the measurement is qualified, first by reference to temperature, and secondly by a statement of the range of variability; a micron is a millionth of a metre. A measure that is correct to one five-millionth is, to all intents and purposes, a constant; it would be to all intents and purposes a constant if the variation were far greater. In strictness, however, it is a variable.

[2] See, for instance, S. P. Langley, *Energy and Vision, Philosophical Magazine*, xxvii., 1889, 1.

a couple of hours of methodical work will settle the question from what height a leaden shot of a given weight must fall upon a glass

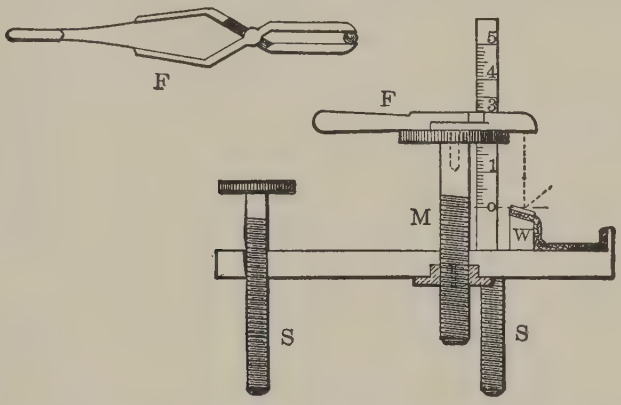


FIG. 26. Acoumeter for determining the Stimulus Limen of Noise. *SS*, set-screws (two of the three are shown), supporting a wooden platform. *M*, micrometer screw at the centre of the platform, with scale beside it. *FF*, spring forceps, lying on the head of *M*, and carrying a small shot for dropping on the glass plate above *W*. The shot rebounds, and falls noiselessly into a padded trough.

plate if the noise is to be just audible to an observer seated 10 m. away. Results of this kind are useful, as means of comparison, but have no general scientific value.

§ 65. **The Just Noticeable Difference as the Unit of Measurement.** — We defined the liminal stimulus, or the just noticeable stimulus, as that magnitude of stimulus which evokes a sensation in one-half of a long series of observations, while in the remaining one-half the result is negative or doubtful. If, now, we take a second stimulus of the same magnitude, and gradually increase its intensity by very small amounts; and if, at every step of this progression, we compare the sensations set up by the two stimuli: then we shall presently arrive at a stimulus-difference which behaves in the same way as the liminal

stimulus itself. We shall, that is, come to a difference which is perceived as a difference in one-half of a long series of observations, while in the remaining one-half there is no perceptible difference, or the observer is in doubt. And the procedure may be repeated, again and again, until we have traversed the whole or a large part of the intensive scale.

It has been suggested that this difference, which is known as the just noticeable difference of stimuli, or as the differential limen of sensation, may be regarded as the natural unit of the scale of sensible intensity. The zero-point of the scale is given with the liminal stimulus, or (as it is called, with reference to sensation) the stimulus limen. The end-point of the scale is given with the terminal stimulus. The units of the scale will then be given with the series of just noticeable differences as defined above. For, it is said, the just noticeable differences correspond to least distances upon the sense-scale, minima of sensible distance. Now least distances, being the smallest possible distances at which sensations can be distinguished, are necessarily equal distances; and equal distances are the very things that we are in search of, to furnish the subdivisions of our mental scale.

Logically, however, this argument is not sound. It is by no means self-evident that least steps, at various parts of the sense-scale, should also be equal steps. A given difference between sensations might be the least perceptible difference, and yet, as compared with another least perceptible difference from another part of the scale, might be larger or smaller. The equality of just noticeable differences must, then, be proved; it cannot be assumed. The appeal lies to the results of experiment.

We shall see in the next § 66 that the results of experiment are ambiguous. Nevertheless, the preponderance of the experimental evidence is, in the writer's judgment, very definitely in favour of the equality of the just noticeable differences; the discrepant results can be accounted for in terms of known sources of error. We return to the point later.

In the meantime: Why, it may be asked, should we not appeal to introspection? Why should we not directly compare two just noticeable differences, from different regions of the intensive scale, and see if they are alike or different? — For the simple reason that they are the results of measurement. If mere observation were enough, we should not need to measure at all, in any field of science. If we could estimate the sixtieths of a circle, it would not be necessary to mark off the clock-face into minutes; if we could estimate spaces of so many feet, it would not be necessary to secure architects' plans before we built a house. The just noticeable difference is not determined by a single introspective observation, and cannot be carried in the head as a standard of magnitude: it is the calculated result of a long series of introspective observations, and stands for a most probable or representative value. The whole object of measurement is to carry accuracy into fields in which mere observation, simple estimation, is inaccurate.

§ 66. **Weber's Law.** — If we determine a series of just noticeable differences, in the middle region of the intensive scale, we find a very simple relation between change of sensation and increase of stimulus. At the beginning, where the stimuli are relatively weak, only a small addition is required to effect a noticeable increase in the intensity of sensation; as the series progresses, the additions become larger and larger; and towards the end, where the stimuli are relatively strong, the largest additions are needed. And this progressive increase of the stimulus-increment is uniform: so that, in general, the series of least sense-

distances corresponds to a series of stimulus-increments that are, approximately, equal fractions of the original stimulus. Thus, if we start with the stimulus 10, and find a just noticeable difference with the stimulus 11, then when we come to 20 we shall find a difference with 22, when we come to 30 we shall find it with 33, and so on.

If, therefore, we could regard all just noticeable differences as equal, — all least sense-distances as equal sense-distances, — we could sum up the results of our experiment by saying that an arithmetical series of sense-distances corresponds to a geometrical series of stimulus-values. We should have, on the side of sensation, a series of intensities 0[1], 1, 2, 3, 4, . . ., lying at points equidistant upon the intensive scale; and we should have on the side of stimulus a progression of the order R, $R(1+r)$, $R(1+r)^2$, $R(1+r)^3$, . . ., where R is the first stimulus taken (here the stimulus 10, correlated with the sensible intensity 0), and r is a certain fractional part of R (here, one-tenth).

We can put the question to the test of experiment. Let us take, for instance, the case of sensations of light. We know, from many investigations, that a succession of just noticeable differences of light-sensation is paralleled by a geometrical series of physical light-stimuli. Now we have recourse to larger, supraliminal differences of light-sensation. We set up on the colour-mixer (Fig. 4) three compound discs of black and white paper. The two outer discs are adjusted to give on rotation a dark and a light

[1] This 0 is not, of course, the zero-point of intensity of sensation at large: it is only the zero-point of our arbitrarily selected scale, and therefore stands for the intensity of sensation with which the experiments begin. — If we are measuring a table with a foot-rule, we begin with 0, in just the same way; but we do not mean that space at large begins where our rule begins.

grey respectively; they remain constant throughout the experiment. The proportion of black and white in the middle disc is varied, until a grey is obtained which lies, for sensation, midway between the extremes. Our three rotating discs then show two equal sense-distances, of much more than liminal extent. What of the stimuli? The stimuli, measured by means of the photometer, prove to form a geometrical series; their photometric values differ, not by equal amounts, but by relatively equal amounts.

Here, however, is the answer to our question. Here we have an arithmetical series of sense-distances, two successive distances guaranteed equal by introspection, corresponding to a geometrical series of light-stimuli. Since, then, we found a geometrical series of stimuli corresponding to our series of just noticeable differences of sensation, it follows that these just noticeable differences must themselves be psychologically equal. The just noticeable difference may be accepted as the unit of the intensive scale.

A strictly methodical procedure is as necessary in this case as it was in the case of the just noticeable difference: we do not discover the equality of the two sense-distances by direct introspection, but we calculate the most probable point of equality from a long series of introspective observations. The difference in the two experiments is this: that in the determination of the just noticeable difference the observer reports the likeness or difference of two sensations, whereas in the present experiment he reports the likeness or difference of two sense-distances. Hence we have, with supraliminal differences, an introspective control that is lacking for the liminal.

At the same time, the change from comparison of sensations to comparison of sense-distances may have a decided influence upon the observer's judgment. We said above (§ 65) that the results

of experiment were ambiguous. As a matter of fact, several recent investigations have led to the result that equal supraliminal distances, determined in the way just described, do not contain — as on our view they should — equal numbers of just noticeable differences, but that, on the contrary, the higher of the two contains fewer just noticeable differences than the lower.[1] And this result has been interpreted to mean that the just noticeable difference is a magnitude that increases with increase of stimulus, so that it cannot serve as the unit of measurement. However, another interpretation is possible. The upper distance, which contains the fewer just noticeable differences, may in reality be shorter than the lower; the observer's judgment that the two distances are equal may be erroneous. For one very dangerous source of error, in experiments upon the comparison of supraliminal sense-distances, is that the observer tends to judge, not in terms of sensation, but in terms of stimulus. He thinks, not of the light-sensations, but of the grey papers; not of the sounds heard, but of the heights from which the balls must have fallen to give those sounds (§ 62). If this error, which is known technically as the stimulus-error, creeps into the observations, then the stimuli which delimit the two sense-distances are likely to form, not a geometrical, but an arithmetical series. The consequence is plain. The upper distance must now contain fewer just noticeable differences than the lower; it is not psychologically, but only physically, equal to the lower. The observer, who was called upon to space out intensities of sensation, has really spaced out, in the light of his everyday experience, characters or properties of material things; and his spacing has, naturally, led to an approximate physical equality. — This, in general, is the writer's explanation of the discrepancies in the experimental results.

The law that equal sense-distances correspond to relatively equal differences of stimulus is known as Weber's Law. It has been found to hold, at least approximately

[1] See, *e.g.*, W. Ament, *Ueber das Verhältnis der ebenmerklichen zu den übermerklichen Unterschieden bei Licht- und Schallintensitäten*, in Wundt's *Philosophische Studien*, xvi., 1900, 135.

and within a certain middle region of the intensive scale, for intensities of noise and tone, of light, of pressure, of various kinaesthetic complexes (lifted weights, movements of the arm, movements of the eyes), and of smell. Its validity in the fields of taste and of temperature is doubtful. It may possibly hold for affection (§ 73), as well as for sensation; but no experimental test in the sphere of feeling has as yet been made.

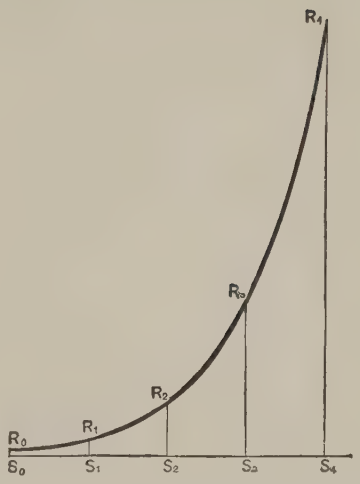


FIG. 27. Generalised representation of the relation between S and R formulated in Weber's Law. Equal sense-steps are marked off as abscissas, and the corresponding R-values are entered as ordinates.

In 1834 the German physiologist E. H. Weber (1795–1878) performed some experiments with weights and visual distances which seemed to establish a constancy of the relative differential limen. He accordingly concluded that "what we perceive, when we are discriminating between objects, is not their absolute difference, but rather the proportion which the difference bears to their magnitude." G. T. Fechner (1801–1887) gave the law a precise phrasing, and put it to elaborate experimental test. Although Fechner's modesty led him to name it after

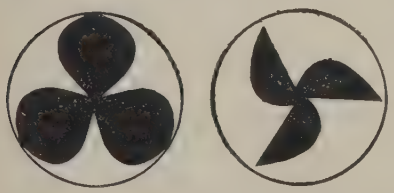


FIG. 28. Pair of black-and-white discs for the demonstration of Weber's Law. The brightness of the left-hand disc increases, from the centre towards the periphery, in geometrical progression; that of the right-hand disc increases in arithmetical progression. — A. Kirschmann, *American Journal of Psychology*, vii., 1896, 386 ff.; E. C. Sanford, *A Course in Experimental Psychology*, 1898, 335 f.

Weber, we might more correctly term it Fechner's Law or the Weber-Fechner Law.

Fechner formulated the law in the equation $S = c \log R$, where S stands for intensity of sensation, R for stimulus, and c for a constant factor. Fechner's understanding of the formula was wrong; he fell into the very common error which we discussed in § 62. The formula itself, however, may be retained. Here is its derivation in terms of supraliminal sense-distances.

We know, from our experimental results, that the magnitude of a sense-distance is dependent upon the quotient of the two R that limit it. Let the dependence be expressed by the mathematical sign of function, f. Then we have, for two successive sense-distances, the equations:

$$\overline{S_1 S_2} = f\left(\frac{R_1}{R_2}\right),$$

$$\overline{S_2 S_3} = f\left(\frac{R_2}{R_3}\right).$$

Adding these equations, we get:

$$\overline{S_1 S_3} = f\left(\frac{R_1}{R_2}\right) + f\left(\frac{R_2}{R_3}\right).$$

But we know, again from our experiments, that:

$$\overline{S_1 S_3} = f\left(\frac{R_1}{R_3}\right)$$

and, of course,

$$f\left(\frac{R_1}{R_3}\right) = f\left(\frac{R_1}{R_2} \cdot \frac{R_2}{R_3}\right).$$

We have, then, finally:

$$f\left(\frac{R_1}{R_2}\right) + f\left(\frac{R_2}{R_3}\right) = f\left(\frac{R_1}{R_2}\right) \cdot \left(\frac{R_2}{R_3}\right).$$

Now the only continuous function that can satisfy an equation of this form is, as we learn from the mathematical text-books, a logarithmic function. Hence we may write (inserting a constant factor, c, to indicate our choice of some particular logarithmic system):

$$\overline{S_1S_2} = c \log \frac{R_1}{R_2},$$

$$\overline{S_2S_3} = c \log \frac{R_2}{R_3}.$$

Or, in general, if S_0 and R_0 denote the S and R with which we start, and S and R themselves denote any other sensation and its corresponding stimulus-value:

$$\overline{SS_0} = c \log \frac{R}{R_0}.$$

And, lastly, if we denote the intensive S-distances reckoned from an initial S_0 by **S**, and the R-intensities calculated in terms of the corresponding R_0 by **R**, we have simply:

$$\mathbf{S} = c \log \mathbf{R}.$$

The formula may also be derived, though not without help from the calculus, in terms of liminal sense-distances or just noticeable differences.

§ 67. **Theory of Weber's Law.** — Every sense-organ, we said in § 64, offers a certain amount of frictional resistance to stimulus; it is this resistance that explains the fact of the stimulus limen. There can be no doubt that the differential limen is a fact of the same order, to be explained in the same way. Whatever the present state of the sense-organ may be, whatever excitatory processes are already in progress within it and within the connected parts of the central nervous system, the same sort of resistance is offered to an incoming stimulus. When the nervous machine has once been started, it will continue to work, without interruption, so long as adequate stimulation is continued: or, in other words, when sensation has once been set up, it will follow, continuously, the changes of stimulus. But if the stimulus cease for a moment to act,

the machine becomes inert, and must be started up again as if it had completely run down.

Intrinsically, therefore, the relation between sense-distance and stimulus-difference, which is expressed in Weber's Law, is a continuous relation; intensity of sensation is a continuous function of intensity of stimulus. In this sense, Weber's Law explains the facts of sensible intensity just as Hering's theory of vision or Helmholtz' theory of audition explains the facts of sensible quality. Weber's Law is itself the theory of sensible intensity. But the continuous function is changed, under certain conditions, into a discontinuous function; we have to explain the limens. And we explain them, stimulus limen and differential limen alike, by reference to the inertia of the nervous mechanism.

An illustration may help to make things clearer. If a magnetic needle is suspended at the centre of a circular coil of wire, and an electric current is sent through the wire, the needle is deflected from its position of rest. The angle of deflection is, however, not directly proportional to the strength of current. As the strength of current is increased, by equal amounts, the deflection of the needle becomes progressively smaller and smaller. The mathematical expression of the relation is very simple. If a is the number of amperes in the current, k a constant, and θ the angle of deflection, then $a = k \tan \theta$. — Here is an expression that is very like the $S = c \log R$ of Weber's Law; and both formulas are the expression of a continuous function.

Now suppose that the needle is hanging steady, whether at the zero-point of its scale or at any other point at which it is held by the current in the coil, and that we increase the current very slowly. At first we get no movement at all. Presently, however, when the current has been increased by a certain amount, the needle goes with a little jump to the position which the formula requires. In this case, we have two phenomena before us. On

the one hand, the needle is a magnetic needle, and the amount of its deflection is a continuous function of the current in the coil. On the other hand, the needle does not move, from any position of rest, without friction; so that under the conditions of our second experiment we observe, not a continuous movement, but a series of jerks. In just the same way, we have for intensity of sensation the continuous function expressed in Weber's Law; but we also have the stimulus and the differential limens as facts of friction.—

From the point of view of experimental psychology, Weber's Law has a very special significance, as summing up the results of the first successful attempt at mental measurement (§ 63). At the present time, methods of measurement, — metric methods, as they are technically called, — have been employed in many other fields of the mental life. Indeed, while little has been done in comparison with what still remains to do, there is no doubt that, in principle, every single problem that can now be set in psychology may be set in quantitative form. The psychological text-books of the next century will be as full of formulas as the text-books of physics are to-day.

The Law is also of great importance in our daily life, since wherever it is valid we are governed, not by the differences, but by the quotients of the intensive stimuli that affect us. It is because Weber's Law holds for a middle range of light-intensities that we are able to ignore the manifold changes of illumination to which we are exposed in the course of the daylight hours. It is for the same reason that the painter, who cannot at all reproduce by his pigments the absolute intensities of light in nature, can nevertheless furnish a recognisably true copy of any natural scene. And again, it is because Weber's Law holds for a middle range of sound-intensities that a large block of seats in the concert-room, at a moderate distance from the stage, can all be sold at the same prices and all have equal advantages for hearing.

References for Further Reading

§§ 62–67. A general account of the problems of mental measurement is given in the author's *Experimental Psychology*, II., i., 1905, Introduction; and an historical sketch of the course of experiment, *ibid.*, II., ii., 1905, Introduction: *The Rise and Progress of Quantitative Psychology*. References of especial importance are: E. H. Weber, *Der Tastsinn und das Gemeingefühl*, an article in R. Wagner's *Handwörterbuch der Physiologie*, iii., 2, 1846, 481 (also published separately, 1849, 1851); G. T. Fechner, *Elemente der Psychophysik*, 2 vols., 1860 (1889, 1907), esp. i., chs. vi.–x.; G. E. Müller, *Zur Grundlegung der Psychophysik*, 1878; *Die Gesichtspunkte und die Tatsachen der psychophysischen Methodik*, 1904 (also in L. Asher and K. Spiro, *Ergebnisse der Physiologie*, II., ii., 266); J. Delboeuf, *Éléments de psychophysique générale et spéciale*, 1883; *Examen critique de la loi psychophysique, sa base et sa signification*, 1883; H. Ebbinghaus, *Ueber negative Empfindungswerte*, *Zeitschrift f. Psychologie u. Physiologie d. Sinnesorgane*, i., 1890, 320, 463; W. Wundt, *Grundzüge d. physiologischen Psychologie*, i., 1908, 525.

AFFECTION

§ 68. **Feeling and Affection.**— The word 'feeling' is used in a great variety of meanings. A thing feels rough or smooth, hard or soft, sharp or blunt, firm or shaky, warm or cold, elastic or brittle, thick or thin, clammy or oily. We ourselves feel hungry or thirsty, fresh or tired, energetic or lazy, strong or weak, well or ill. We also feel comfortable or uncomfortable, we feel at home or strange, at ease or ill at ease, natural or constrained; we feel happy, cheerful, restless, angry, irritable, eager, calm. We feel hopeful, despondent, grieved, hurt, injured, relieved, contented, gloomy, anxious, annoyed. We feel indifferent, and we feel sympathetic; we feel the difficulty of an objection, the truth of an argument, the nobility of a character, the sacredness of a belief. 'Feel' and 'feeling' seem, indeed, to be psychological maids of all work; they can do, in the sentence, practically anything that a verb and a substantive can be called upon to do. There is little hope, one would think, of turning them to strict psychological account, and of giving them a place in a list of technical terms.

Let us see what happens, however, if we contrast feeling with sensation. Suppose that I say to you: The organism not only senses, but also feels; consciousness is made up, not of sensations alone, but of sensations and feelings. Here, surely, there is a hint or suggestion, vague though it may be, of the true psychological meaning of

'feel' and 'feeling.' You realise that stimuli do something more than arouse sensation; they give rise to processes of a different kind, to 'feelings' in a special sense; we do not merely take the impressions as they come, but we are affected by them, we feel them; and what we feel is their agreeableness or disagreeableness, their pleasantness or unpleasantness. Colours and tones, tastes and smells, may be pleasing or unpleasing just as obviously and just as directly as they are red or *c*, bitter or musky; and their pleasant or unpleasant character is a matter of feeling.

We have gained something, then, by contrasting feeling with sensation; we have found a fairly definite meaning for the term, and we have marked off a new field of mind for further study. At this point, unfortunately, the views of modern psychologists begin to differ; the psychology of feeling is still, in large measure, a psychology of personal opinion and belief. The writer holds that there is an elementary affective process, a feeling-element, which in our own minds is coordinate with sensation and distinguishable from it, but which is nevertheless akin to sensation and is derived from the same source, made (so to speak) out of the same kind of primitive mental material: this elementary process is termed affection. He holds, further, that there are only two kinds or qualities of affection, pleasantness and unpleasantness. The principal reasons for and against this view are set forth in the following sections.

If we look carefully at a list of 'feelings,' such as that given at the beginning of this § 68, we find that the experiences in question fall into three main groups. We have, in the first place, certain perceptions of touch: hardness, roughness, solidity, etc. We have, secondly, certain complexes of organic sensations: hunger,

fatigue, etc. And we have, thirdly, a number of mental processes which differ markedly in various ways, but which are all characterised by the predominance of pleasantness or unpleasantness: joy, sorrow, anger, difficulty, etc.

In ordinary speech, we oppose 'feeling' to 'intellect'; the man who is swayed by feeling is contrasted with the man who acts coolly and deliberately, by reasoned judgment. This use of the term is so natural and so habitual that we shall do well to keep it in psychology. 'Feeling' will then be the general name for all sorts of pleasant-unpleasant experience, for every form of emotion, mood, sentiment and passion. All the items in the third division of our list will be rightly called feelings.

But 'feeling' is also used, in psychology, in a narrower and more technical sense. It denotes a simple connection of sensation and affection, in which the affection preponderates. Hunger, for instance, is a sensation. But we may speak of a feeling of hunger if we mean a jolly hunger or a gnawing hunger; if, that is, we mean a pleasantly stimulating or an unpleasantly insistent hunger. Pain, again, is a sensation; and it is a sensation that, at different intensities and under different circumstances, may be pleasant, indifferent, or unpleasant. Usually it is unpleasant, and strongly unpleasant. When this is the case, we speak in psychology of a feeling of pain. And in just the same way we may speak of a feeling of fatigue, of nausea, of drowsiness, of freshness, of bodily strength. All the items in the second division of our list are rightly called feelings, in this narrower meaning of the term, provided that the sense-quality is accompanied by an intensive affection, pleasant or unpleasant. They are feelings proper, or sense-feelings.

The items of the first division are not feelings at all, but perceptions; and they are termed perceptions, as well as feelings, in the language of everyday life. In their case, psychology has no choice; the name 'feelings' must be given up. We shall, however, have something further to say about them in § 69. —

In summary, then, we have the following terms. *Affection* is an elementary mental process. Affection is the characteristic element in emotion, in love and hate, joy and sorrow, just as sensa-

tion is the characteristic element in perception, and image the characteristic element in idea (§ 10). *Feeling* in the narrower meaning of the word, sense-feeling, is a simple connection of affection and sensation, in which the affective element predominates: in this sense we are said to feel sleepy, tired, hungry, rested. *Feeling*, in the wider meaning of the word, is the general name for the affective side of our mental life: in this sense we are said to feel glad or sorry, worried or hopeful, proud or ashamed. There is no reason why the two meanings of 'feeling' should lead to confusion, and we shall be careful not to confuse them in this book.

§ 69. **Affection and Sensation.** — We have now to enquire into the nature of affection, considered as an element of mind; to ask how it resembles and how it differs from sensation. We will take the resemblances first.

Sensation was defined, in § 12, as an elementary mental process which is constituted of at least four attributes, — quality, intensity, clearness and duration. Now affection has three of these attributes, — quality, intensity, and duration; it thus appears as a process of the same general kind as sensation, and it may be defined on the same lines, by reference to attributes which are common to both. Affection has qualities: it has at least the two qualities of pleasantness and unpleasantness, and (as we shall see in § 72) some psychologists believe that it has many more. Affection shows differences of intensity: an experience may be mildly pleasant, slightly disagreeable, or wonderfully pleasant, unbearably disagreeable. And affection shows differences of duration: pleasure may be momentary, or may persist as a permanent mood; and unpleasantness behaves in the same way. So far, then, there is a general resemblance between affection and sensation.

Again: we have seen that certain sensations show the

phenomenon of adaptation. In many departments of sense — in pressure, in temperature, in smell, in taste — a sensation may disappear, fade out of consciousness, if the stimulus is continued. Sight, too, obeys the law of adaptation. We do not, it is true, become blind under visual stimulation; but our vision is reduced to a neutral grey, the quality of the persistent central excitation (§ 18). Precisely the same phenomenon of adaptation appears in the case of affection. If we are exposed for a long time together to the same stimulus, we may cease to be affected by it at all. The cookery of a foreign country is, when we first make acquaintance with it, distinctly pleasant or unpleasant; but in either case it quickly becomes indifferent. Dwellers in the country do not find the pleasure in country sights and odours that the townsman does; they have grown used to their surroundings. The whir of a sewing machine in the room above that in which we are working may at first be extremely annoying; but as we become accustomed to it, its unpleasantness disappears. There is, indeed, no region of mind in which this law of affective adaptation fails to manifest itself. During the first few weeks of our stay in a beautiful neighbourhood we may be continually delighted with the colours and forms of the landscape. But we soon grow indifferent to them: fields and hills and streams are seen as clearly as ever, but they have ceased to excite pleasure. On the other hand, a piece of vulgarity which at first offends us may be taken as a matter of course if constantly repeated among those in whose company we are thrown. Here is a second point of likeness between affection and sensation.

The fact of affective adaptation seems to show as clearly, in these instances, as the fact of olfactory adaptation showed in the

instances of § 32. Nevertheless, it has been disputed; some psychologists explain the phenomena in terms of sensory adaptation. It is, they say, the cookery and the landscape that we grow accustomed to, not the disagreeableness of the dishes and the beauty of the landscape. There are, that is, as many possibilities of sensory adaptation as there are attributes of sensation; we may become adapted to intensity and clearness and duration, precisely as we become adapted to quality. If a friend asks us: "Doesn't that sewing machine annoy you?" we shall be likely to reply: "No! it would if I heard it, but I simply don't hear it any more." And the answer, these psychologists say, is correct; we have become adapted, not to the quality of the noise, but to its intensity and clearness; we have ceased to attend to it; it is no longer effective as a stimulus, and so its original disagreeableness has naturally lapsed. We have grown used, not to the disturbance, but to the noise; and the noise is now, as a result of our adaptation, both weak and obscure.

In the case of the sewing machine, this explanation is possible. But it is not convincing; for we may very well have become adapted both to the sensation and to the affection; the two adaptations may have gone along side by side. And in other cases, in which the stimulus is not continuous but intermittent (mealtimes, country walks, the behaviour of acquaintances), affective adaptation seems obvious. I may be keenly aware of the odour of garlic, and yet be entirely indifferent to it. I may take sharp note of the fact that the person with whom I am talking begins to use his toothpick, and yet have no feeling of disgust. We shall see, in § 78, that it is possible to attend without feeling; and if it is, if the sensation that fills the chief place in consciousness may be indifferent, then affective adaptation is certain. The objection shows, however, — what we have already insisted on, — that it is hardly possible to take a single step in the psychology of feeling without meeting contradiction and conflict of opinion.

Thirdly, the processes of pleasantness and unpleasantness show a strong introspective resemblance to organic sensations. Pleasantness seems akin to health, drowsiness,

bodily comfort, repletion; unpleasantness seems akin to pain, bodily discomfort, over-fatigue, lassitude. No doubt these experiences, as they present themselves in everyday life, are more than sensations; they are sense-feelings, complexes of affection and sensation; the total conscious experience that we call health, for instance, contains a pleasant affection along with various, kinaesthetic and other, sensory processes. Still, if we analyse repletion or fatigue, and so far as possible set off the affective element from the constituent sensations, the resemblance appears to persist. Affection is like organic sensation in much the same sense in which sensations of taste are like sensations of smell (§§ 29, 36).

In fine, affection resembles sensation in the nature of its attributes and in its behaviour when a stimulus is long continued, while the qualities of affection, pleasantness and unpleasantness, show an intrinsic likeness to the qualities of organic sensation. What, now, are the differences?

The first difference is this: that affection lacks the attribute of clearness. Pleasantness and unpleasantness may be intensive and lasting, but they are never clear. This means, if we put it in the language of popular psychology, that it is impossible to attend to an affection. The more closely we attend to a sensation, the clearer does it become, and the longer and more accurately do we remember it. But we cannot attend to an affection at all; if we attempt to do so, the pleasantness or unpleasantness at once eludes us and disappears, and we find ourselves contemplating some obtrusive sensation or image which we had no desire to observe. If we want to get pleasure from a concert or a picture, we must attend to what we hear

and what we see; so soon as we try to attend to the pleasure itself, the pleasure is gone.

The lack of the attribute of clearness is sufficient, in itself, to differentiate affection from sensation; a process that cannot be made the object of attention is radically different, and must play a radically different part in consciousness, from a process which is held and enhanced by attention. And it should be noted that lack of clearness distinguishes affection from organic sensation as definitely as from sensations of sight or hearing; we have no difficulty in attending to the sensory components of hunger and thirst and fatigue.

There is, however, a further difference. Pleasantness and unpleasantness are, what their names imply them to be, opposites. The opposition is not a matter of contrast, as this term is used in the psychology of sensation, although it is often referred to as contrast: it is rather a matter of incompatibility in consciousness. There is no similar opposition of sensory qualities.

It was said in § 26 that tones are intrinsically harmonious, colours intrinsically antagonistic. This statement means that the nervous processes underlying visual sensation are antagonistic, and that colours themselves offset one another, show one another up; whereas the nervous processes aroused by the sympathetic vibration of the basilar fibres are confluent, synergic, and tones themselves show a tendency to blend or fuse with one another. It must, however, be understood that the antagonism of visual sensations is not at all the same thing as the incompatibility of pleasantness and unpleasantness: for, first, the antagonistic qualities of black and white are actually connected by the series of greys, due to the admixture of the central grey; and we might, with similar aid from the centre, obtain series of sense-qualities connecting *R* with *G*, and *B* with *Y*. Pleasantness, on the other hand, is con-

sciously at odds with unpleasantness; the opposition of the two processes belongs to the essence of them as experienced. And secondly, there is no such thing as affective contrast, in the strict meaning of the term; the pleasure of convalescence is not enhanced by the unpleasantness of past suffering, as red is enhanced by green. Convalescent comfort is itself the opposite, the conscious antithesis, of the discomfort of sickness; but it is not influenced by that discomfort.

It is true, however, that we often speak loosely of contrast when we are referring to affective opposition. An ordinary man, seen by the side of a dwarf, looks unusually large; the same man, seen by the side of a giant, looks unusually small. We say that he looks large and small by contrast. The fact is that we feel a sort of contemptuous pity for the dwarf, and a surprised admiration for the man beside him; and again, a contempt for the man and an admiration for the giant. What we have laid to the account of a spatial contrast is really due to affective opposition. —

It is worth noting that this affective opposition is reflected in certain of the cutaneous perceptions that in ordinary speech are termed feelings (§ 68). We oppose warmth and cold, — not as sensory qualities, for they belong to different senses; but as pleasant and unpleasant. On the whole and in general, warm and smooth and soft things are pleasant to the touch, and cold and rough and hard things are unpleasant. Indeed, whenever we find in consciousness an opposition of this sort, we may be sure that it is an opposition due to the presence of affective processes alongside of the sensations. And in so far as we oppose warmth to cold, smoothness to roughness, for affective reasons, in so far there is some justification for giving these processes the name of feelings.

Other Distinguishing Characters of Affection. — We have distinguished affection from sensation on the negative ground of lack of clearness, and on the positive ground of qualitative opposition. It has been urged, further, that sensations are the objective and affections the subjective elements of consciousness. No one, however, has found a satisfactory psychological definition of these terms. We may, perhaps, call sensations objective in the sense

that they can stand alone in consciousness, independently of affection; and we may call affections subjective in the sense that they never appear alone, but always and of necessity as the companions of sensation. But this is itself a disputed point. Again, it is urged that all sensations may be localised in space, while affection is not localisable. But it is argued, on the other side, that tones and odours sometimes resist all our efforts to place them; while the pleasantness of a sweet taste, and the unpleasantness of an organic pain, are localised along with the taste and the pain themselves. Yet again, it is urged that the sensation is normally more intensive than the image, the perception than the idea; but that the affection which accompanies the idea is normally more intensive than that which accompanies the perception. But, if one psychologist informs us that "only the very highest degrees of sensory agreeableness and sensory disagreeableness are now able to overpower the 'higher' feelings," another asserts, just as positively, that "ideal pains and pleasures are not comparable in mere intensity with sensuous pains and pleasures." Contradiction could hardly be flatter!

In all these controversies, the writer leans to the affirmative side, the side which affirms a difference between affection and sensation. He does not believe, for instance, that a purely affective process may enter consciousness alone, as the herald of a coming sensory process, or that it may lag behind in consciousness alone, after its sensory companions have disappeared, — although both these statements are freely made. He finds a sort of flimsiness or softness or yieldingness in the texture of pleasantness and unpleasantness; their quality is like that of certain organic sensations, but they are less hard, less stable, less self-supporting. This difference, which is difficult to express in words, is probably connected with the presence or absence of the attribute of clearness; but there is no reason why it should not be termed a difference of objective and subjective. Again, the writer believes that affections are always coextensive with consciousness, diffused over all the sensory contents present at the time; and that, if the pleasantness of a taste is localised in the mouth, that is simply because consciousness itself, under the experimental conditions, has been

narrowed down to a taste-consciousness. Finally, there seems to be no doubt that, in the adult human mind, the ideal feelings are usually stronger than the sensuous. I fall down on a slippery path, and hurt myself; but my first thought is "How stupid of me to slip!" I sit in a draughty concert hall with the certainty of a neuralgia; but I am afraid of making myself ridiculous, and so I remain in my chair. It is a raw evening, and I have a little cold; but I go to see my friend, because I do not want to disappoint him. Were it worth while, illustrations of this kind could be multiplied a hundredfold. It is not worth while, because the question at issue cannot be decided by casual observation. Divergence of opinion is inevitable, until the experimental method has been brought to bear, systematically, upon the problems of feeling. In the meantime, we must be content to mark off affection from sensation by the two salient characters described in the text.

The Question of Mixed Feelings. — It would seem that, if pleasantness and unpleasantness are opposite and incompatible, they cannot coexist in the same consciousness, — that we cannot feel pleased and feel displeased at one and the same moment. A consciousness, however, is a very complicated affair; it is made up of a large number of elementary processes; and there is no doubt that the nervous system may be exposed, in different quarters, to stimuli some of which, if felt by themselves, would be felt pleasantly and some of which, if felt alone, would be felt unpleasantly. Hence it becomes a question of fact whether these various stimuli, acting together at the same time, give rise to a single resultant affection, either pleasant or unpleasant; or whether every stimulus sets up its own localised affection, so that consciousness may be a mosaic of separate pleasantnesses and unpleasantnesses.

Language favours the second alternative. We go back to school after the holidays with mixed feelings; we visit our old home, after a long absence, with mixed feelings; there is, indeed, hardly anything that we may not look upon, or look back or forward to, with mixed feelings. Juliet tells us that parting is sweet sorrow, a pleasant unpleasantness; and Tennyson's Geraint watches the

mowers, whose dinner he has just eaten, with humorous ruth, that is, with a pleasantly unpleasant feeling. There is no pleasure, we are told, without its alloy of pain; there is no despair so dark that it is not lightened by a ray of hope. Popular psychology makes no question about mixed feelings; and a psychologist of standing writes that "almost all mental states which are marked by strong feeling in the case of developed minds are mixed feelings."

On the other hand we know that a single trifling annoyance may colour our whole mood. When Othello behaves unkindly to Desdemona, she excuses him on the ground that he is worried by affairs of state; "for let our finger ache," she says, "and it indues our other healthful members ev'n to that sense of pain." We know, too, that if we are in a particularly good temper we take everything good-temperedly; we may even ask pardon of the man who has trodden on our corns. And there is really no proof that the pleasantness and unpleasantness of the mixed feeling are strictly coincident: Juliet may be alternately glad and sorry; sorry now to part from Romeo, but glad the next moment that he is there, as her lover, to be parted from, and glad a moment after in the thought of seeing him again. How quickly the pendulum of feeling may swing we see in the case of the child, who is crying bitterly at its hurt and then, within a few seconds, is smiling over a lump of sugar.

The final appeal lies, of course, to experiment. Unfortunately, but few experiments have so far been made, and the results of these few are not wholly clear. It is safe to say, however, that the tendency of the experimental evidence is decidedly negative; mixed feelings are, in the laboratory, the exception and not the rule; and the exceptional cases are themselves not above suspicion. The writer has never found, in his own experience, a definite and unmistakable case of mixed feeling.

§ 70. **Other Views of Affection.** — Affection, as we have described it, is an elementary mental process that is both like and unlike sensation. The resemblance is so great that the two processes are evidently derived from a com-

mon mental ancestor; the difference is so great that we have no choice but to rank affection, in human psychology, as a second type of mental element, distinct from sensation.

There are, however, many psychologists who would refuse to accept these statements. Some look upon affection as an attribute of sensation, on a level with quality or intensity; they speak of the feeling-tone or the affective tone of sensation, and not of a separate affective process. Others identify affection with a certain kind of sensation; pleasantness, they say, is a diffuse sensation of tickling, or a weak sensation of lust; unpleasantness is a low intensity of cutaneous or organic pain. Others, again, think that the same processes may appear sometimes as organic sensations and sometimes as affections, according as they are isolated in consciousness, analysed out by attention, or are given in a mixed medley of unanalysed experience.

The first view, that affection is an attribute of sensation, is easily disposed of. For affection has attributes of its own, — quality, intensity, duration; whereas the attributes of sensation are ultimate phases of an elementary mental process, and cannot by any effort of abstraction be factorised into simpler components. Moreover, if any single attribute of sensation is reduced to zero, the sensation disappears: a sensation that has no quality, or no intensity, or no duration, is not a sensation at all; it is nothing. But a sensation may be non-affective, perfectly indifferent, and still be far removed from disappearance. This view, then, may be dismissed from consideration.

Nor does the second view seem to be more tenable. All these sensations, tickling and lust and pain, may become clear, may be made the object of attention; indeed, they

are, so to say, naturally clear, precisely the sort of sensations that we are obliged to attend to. But we cannot attend to affection. Again, all three sensations have their own quality as sensations. We have not fully described tickling or lust when we have dubbed it pleasant; we have not fully described pain when we have dubbed it unpleasant. Tickling has a ticklish quality, that is peculiar to it as sensation; lust has a specific quality, which differentiates it from tickling; pain has a peculiar quality of itch or ache or thrill. An experience which is both ticklish and pleasant, or is both itchy and unpleasant, cannot be identified with pleasantness or unpleasantness; it is something more. And finally, tickling and lust may, with change of circumstances, be either pleasant or unpleasant, and the same thing holds of pain; the scratching of an irritated area of the skin may be at once painful and distinctly pleasant. While, however, these arguments appear unanswerable, it is nevertheless true that the theory which they oppose is held by a large number of modern psychologists.

The third view tries to reconcile the belief that affection is a second form of elementary process with the belief that it is only a certain sort of sensation. We have, it says, various obscure and confused experiences which, ordinarily, we take as they come, without asking what they are made up of. So long as we do this, the experiences present themselves as pleasantness or unpleasantness; but if we scrutinise them, and analyse them into their elements, then they reveal themselves as complexes of organic sensation. The reply is, surely, that experiences which may be analysed into organic sensations are complexes of organic sensations, and nothing more or less; but that, if an experience is pleasant or unpleasant, then the pleasantness or unpleas-

antness remains, no matter how many organic sensations are found along with it. Unless affection is organic sensation, — and we have declined to admit that affection is a sensation of any kind, — the third view is untenable.

It is impossible here to discuss or even to mention all the views that have been held by psychologists concerning the nature of affective experience. Affection has been described, for instance, as a relation, whether between sensations or between a particular sensation and all the rest of consciousness. There is some ground for both opinions. Certain combinations of tones are pleasing, certain others displeasing; certain architectural proportions are beautiful, certain others are ugly. These facts tell in favour of the first theory. Again, a sensation that now enters consciousness enters into relation with all the contents of consciousness, and must, so to say, make its terms with those contents. If it fits in easily among them, it will probably be pleasant; if it disturbs or suppresses them, it will probably be unpleasant. All this tells in favour of the second theory. Nevertheless, both theories alike are to be rejected. Against the first we must urge that affection is not always dependent upon the relation between sensations, but may attach to a single sensation; and, besides, that affection, even if dependent upon sense-relations, need not on that account be itself a relation. Against the second we must urge, in the same way, that the fitting-in of the new sensation, or its reverse, is purely a matter of the behaviour of sensation; it is not necessarily accompanied by affection; still less is it to be identified with affection.

Affection has also been described in terms of mental attitude. It has been defined as such an attitude: affective experience, we are told, is made up of one's own attitudes, and sensory experience of the impressions that one receives: and it has been defined as a character of mental process that depends upon and represents one's personal attitude. In its cruder forms, this theory implies the existence of that permanent mind, that mind-substance or mind-animal, which we rejected in § 3. But even at the best we

may well enquire whether it does not put the cart before the horse. Does feeling represent our mental attitude, or is our mental attitude the expression of feeling?

§ 71. **The Methods of Investigating Affection.** — There are two chief difficulties in the way of an experimental treatment of the affective processes. We cannot attend to pleasantness or unpleasantness; and we can describe our affective experience only in a roundabout way. The first of these difficulties needs no further discussion; we have seen that affections lack the attribute of clearness. The second difficulty arises from the fact that spoken language is a language not of feeling but of idea. If I say 'I am very angry,' you know that I am angry; I have given you the idea of my anger; but I have, after all, merely indicated my feeling, and not described it. And even if I should attempt a detailed description, my account — so far as it referred to the pleasantness or unpleasantness of the anger — would still be an account at second hand; I should be obliged to translate my affection into an idea of affection. There is, it is true, a language of feeling: the language of exclamation and gesture. But we have learned, in the course of civilisation, to repress our emotions; we rarely use this language; if on occasion we wish to do so, we are apt to make ourselves ridiculous; and the language itself is but little developed in comparison with speech.

Partly on account of these difficulties, and partly for other and historical reasons, experimental psychology has, until recently, neglected the study of affection. The problems that were at first attacked in the psychological laboratory were suggested by physics and physiology and astronomy: the problems of mental measurement (§ 63), of

the number and nature of the sensory qualities and of their relation to the organs of sense (§§ 14 ff.), and of the duration of mental processes. Feeling had no place in the programme. Now, however, that psychology has gone far enough to experiment on its own behalf, without suggestion from its neighbours, the study of feeling has begun. There are two experimental methods at present in use: the method of impression and the method of expression.

(1) The method of impression has taken various forms, the most promising of which is the method of paired comparisons. In this, a series of similar stimuli is laid out, and the stimuli are presented to the observer two at a time; care is taken that every member of the series is paired with every other member. We may have, for instance, a series of squares of differently coloured paper, numbered in order 1 to 50. We cut two square windows in a sheet of neutral grey cardboard, and show the colours in these windows; the series of observations is so arranged that colour 1 shall be shown along with 2, 3, 4, . . . up to 50; colour 2 with 3, 4, 5, . . .; and so on. In a first experiment, the observer may be asked, as the successive pairs are exhibited: Which of the two colours is the more pleasant? In the next experiment: Which of the two is the more unpleasant? And the series may be repeated as often as seems necessary. The introspective task is extremely simple: the observer has merely to be passive, to let himself go, to allow the stimuli to take affective possession of him. He need not even speak; all that he has to do is to point towards the window which contains the more pleasant or the more unpleasant colour; and the experimenter then records his choice.

At the end of an experiment, every colour has received a

certain number of choices, proportional to its affective value; a very agreeable or very disagreeable colour will have been preferred many times over, a colour that is hardly more than indifferent will have been chosen but rarely. If, now, the names or numbers of the colours are arranged in order, 1 to 50, along a base line, and the number of preferences is indicated in every case by the length of a vertical line erected upon this base, then the smooth curve which joins the tops of the verticals may be termed the affective curve for the particular observer; it is a curve whose course directly expresses his affective response to colour stimuli.

The method may be put to various uses: here is an illustration. We have argued, in § 69, that pleasantness and unpleasantness are opposite and incompatible. If we have recourse to the method of paired comparisons, we can prove that they are opposite. Experiments made with series of coloured papers, series of musical tones, and series of rhythms (rates of metronome beats) give affective curves for pleasantness that are just the reverse of the same observers' affective curves for unpleasantness: stimuli that receive a large number of choices in the experiment on pleasantness receive a correspondingly small number in the experiment on unpleasantness. To prove a thing like this may look like proving the obvious. But, in fact, nobody knew for certain, until these experiments had been made, that pleasantness and unpleasantness were opposite; psychologists might believe, but they did not know. And besides, things that look obvious are oftentimes, in science, the things that very particularly call for proof.

The method may also be used to measure the individual differences in affective response to stimuli. We say that there is no disputing about tastes; and we tend to think, in general, that sensations are experienced in the same way by all normal persons, but that affections are experienced differently, individually, personally. In reality, sensations are less stable and affections are more stable than we suppose. For sensations are changed and shifted by the

varying conditions of adaptation, contrast, attention; while the affective curves of a number of different observers are sufficiently alike to show that, under the same circumstances, all normal persons react affectively in very much the same way.

The method of impression can do us further service. The simple introspective task which it sets is repeated, over and over again; the introspective experience acquired during a series is cumulative, all of the same kind. Hence the observer is able, in the intervals between successive series, to make a full report upon the affective consciousness: he can describe the course of the sense-feeling, take note of anything like a mixed feeling, state whether the agreeableness or disagreeableness of the stimuli was always of the same kind or showed differences of quality, and so on. It is, indeed, to this method that we must mainly look for a settlement of the vexed questions of affective psychology. The work is laborious, and consumes a great deal of time. But the method offers the advantage of a twofold control: an external control by the affective curve, the objective record of the distribution of preferences; and an internal or subjective control by the accompanying introspection.

(2) The method of expression seeks to record the bodily changes which accompany the passage of an affection through consciousness. Just as we express emotion by smiling or frowning, by laughter or tears, by clapping the hands or shrugging the shoulders, so do we express the simplest affective experience by a change of various bodily functions. Tests have been made of pulse, respiration, the volume of a limb, involuntary movement, muscular strength, and the response of the bodily tissues to the electric current.

Physiology has long been in possession of instruments that furnish the records required, and psychology has borrowed these instruments and has adapted them to its own purpose. Take pulse, for instance. We know that the pulse can easily be felt in the wrist, over the radial artery. Now suppose that a small tin funnel is covered, at the wide end, by thin rubber sheeting; and that the sheeting is laid over the artery, and the funnel tied to the wrist. At every beat of the pulse, the rubber will be lifted, and a puff of air will be sent out from the small end of the funnel. Connect this end, by a piece of stiff-walled rubber tubing, to the small end of another funnel, whose wide end is similarly covered with rubber sheeting. Hinge to the lip of the second funnel a light splinter of bamboo; let the splinter lie across the rubber sheeting,

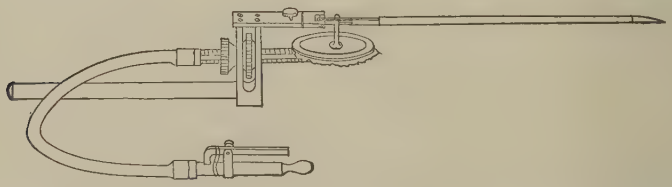


FIG. 29. Marey tambour (rubber-faced funnel) with writing lever, rubber tubing, and air-cock. The tubing is continued from the air-cock to the tambour on the wrist.

and let it rest in the middle on a tiny disc of cork cemented to the rubber. Whenever a puff of air is sent from the first funnel, by the pulse beat, the cork disc of the second funnel will be lifted, and the splinter will rise with it. Now take a piece of glass, that has been smoked over a gas flame, and set it up, in the vertical position, so that the free end of the splinter rests lightly against it. It is clear that, as the pulse rises and falls, the bamboo point will rise and fall on the glass, and will trace a clear line in the soot. And if the glass be drawn slowly forward at a constant rate, a pulse-curve will be traced which shows the rate and the height of the successive beats. Then the glass may be sprayed with varnish, and we have a permanent pulse record.

This is a rough indication of what is called the graphic method. In practice, the instruments are much more complicated and in-

genious. The bodily change may be transmitted to the bamboo stylus not by air but by a system of rigid levers, or by the electric current. And in place of the glass plate we use a kymograph, a brass drum covered with smoked paper, which may be revolved at varying rates. To ensure accuracy in the interpretation of the curve, time-markers are employed, which trace a time curve (in seconds, or half seconds, or fifths of a second, or even in much smaller units) below the curve of pulse or breathing. In principle, however, the tin funnels and the smoked glass plate represent the method.

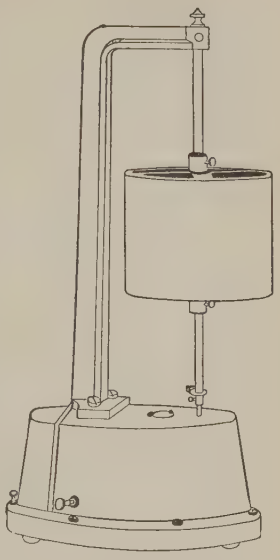


FIG. 30. Clockwork Kymograph.

The instrument which registers the height and rate of pulse is termed the sphygmograph. Similar instruments, tied round the chest or abdomen, register the course of thoracic and abdominal breathing: they are called pneumographs. Volume is registered by the plethysmograph, a large glass jar, partly filled with warm water, in which the hand and forearm of the subject are placed. A glass tubule leads off from the jar, by way of rubber tubing, to the recording funnel or tambour; as the arm swells, the water in the jar rises, the air above it is compressed, and the stylus is thrown up. Involuntary movement is registered by the automatograph, a form of the planchette or ouija-board which still figures

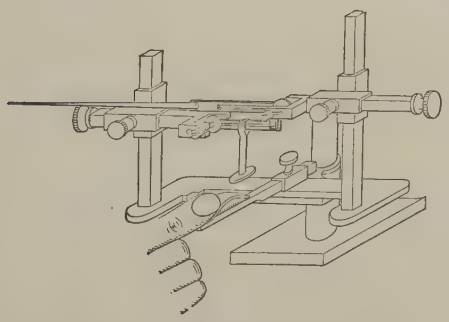


FIG. 31. Franck's Volumetric Sphygmograph (mechanical transmission by means of a system of levers).

largely in spiritistic seances. A board is slung from the ceiling, so that it lies horizontally just over the surface of a table; a pointed glass rod stands vertically in a hole pierced at its forward end. On the table, under the point of the rod, is spread a sheet of smoked paper. If the arm is laid carefully on the board, and left to itself, the glass point traces on the paper the record of its involuntary movements. Muscular strength is registered by the dynamograph or ergograph: in the former, the hand grips a steel spring, the compression of which sends a puff of air through the transmitting system to the stylus; in the latter, the finger pulls repeatedly against a weight or a spring, and the cord upon which it pulls carries a stylus which writes directly upon the kymographic surface. Lastly, in order to measure what has been termed the psychogalvanic reflex, two electrodes, which are connected with a battery giving a constant current and with a sensitive galvanometer, are applied to the hands or to other cutaneous surfaces; an affective stimulus is then presented to the subject, and the resulting deflection of the needle of the galvanometer is recorded.

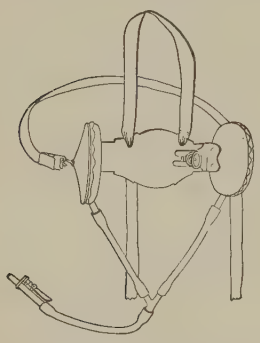


FIG. 32. Pneumograph.

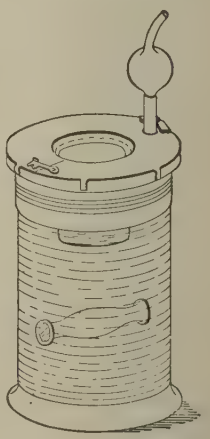


FIG. 33. Franck's Plethysmograph.

In every case, the procedure of the experiments is the same. First of all, a normal reading is taken from the instruments: the experimenter assures himself that the subject is in an indifferent frame of mind, and without applying any stimulus takes a curve of pulse, breathing, or volume; or allows the stylus of the automatograph to record the involuntary tremor of the arm; or obtains an ergographic record; or notes the constant position of the galvanometer needle. Then he applies some agreeable or disagreeable stimulus, and the record is made while the sense-feeling

is running its course. The experiments are repeated again and again; and finally the experimenter tries to discover, from his tracings and notes, the exact correlation between affective quality and the bodily change which expresses it.

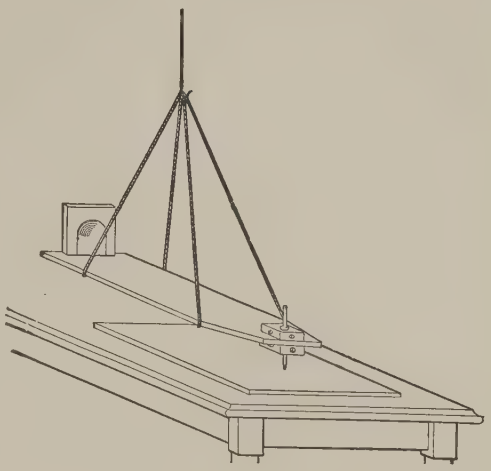


FIG. 34. Automatograph.

The method of expression was introduced into experimental psychology with great expectations; and the results of the first experiments seemed clear and definite. All the bodily functions were heightened and strengthened in pleasure, and all were weakened and depressed in unpleas-

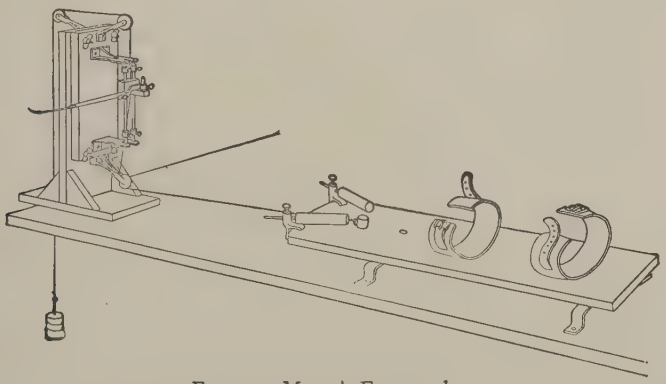


FIG. 35. Mosso's Ergograph.

ant states of mind. A leading psychologist compared the method to 'an extraordinarily delicate chemical rea-

gent' for the detection of pleasantness and unpleasantness. Very soon, however, these dreams were dispelled. The

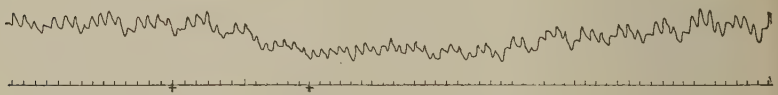


FIG. 36. Part of a tracing obtained with the Franck plethysmograph, one-third actual size. The small waves indicate pulse, the large waves breathing. Change of volume is indicated by the varying height, above the time-line, of the entire tracing. An unpleasant stimulus was applied at the moment marked by the left-hand cross, and removed at that marked by the right-hand cross. The unit of the time-line is 1 sec.

changes in the curves are not correlated, unambiguously, with changes of affective experience: they depend in part upon purely physiological factors, and in part upon other psychological processes, — for instance, upon attention.

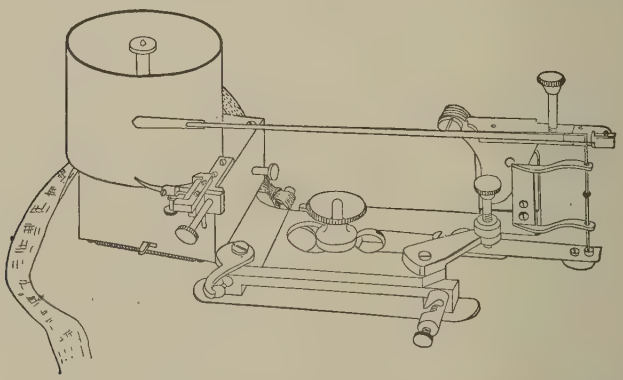


FIG. 37. Von Frey's Sphygmograph. The entire apparatus is bound upon the wrist, the button at the extreme right resting on the artery. The movements of the writing-lever are recorded on a very small, light drum, driven by a clockwork which is housed in the square box to the left. The clockwork also actuates a time-marker, shown in the Fig. at the lower edge of the drum.

Indeed, the simple application of even a weak stimulus appears to throw the whole body, as it were, into reverberation; you cannot show the observer a wall-paper pattern without by that very fact disturbing his respiration and

circulation. If the automatograph proves that the organism involuntarily expands, reaches out, in pleasure, and involuntarily withdraws, shrinks back, from the disagreeable, it proves also that you reach out when you think of a house across the street, and shrink back when you think of the person behind you. There may be a general rule that pleasantness goes with quick and shallow breathing and slowed pulse, unpleasantness with slow and deep breathing and quickened pulse; such an antagonism would well express the opposition of the affective qualities. But there can be no doubt that these changes in pulse and respiration may be otherwise occasioned, and that the appearance of the affective correlation depends upon conditions that are, as yet, only imperfectly understood. Pulse, for instance, has been found to quicken when the stimulus is a pleasant taste, and to slow when it is a pleasant tone or colour; and breathing appears to vary in its behaviour with different individuals.

So far, therefore, we have gained little from the method except a number of divergent results, and the conviction that, before these results can be psychologically interpreted, we must know a great deal more than we do of the bodily functions involved.

It has recently been suggested that the methods of impression and expression might profitably be combined, the registration of physical expression serving as an objective check upon the observer's introspective report, and the introspection in its turn being used for the interpretation of the objective record. It is, of course, feasible to register the course of pulse or breathing during an entire series of experiments by the method of paired comparisons. But the registration would hardly be worth while, unless the introspective task set to the observer were greatly complicated; and then we should lose one of the chief advantages of the method.

It therefore seems best to continue work by the method in its present form, and to wait patiently for the time when increased knowledge shall give us the required understanding of the physiological processes.

It may be added that the psychogalvanic method, though in principle it dates from 1888, has only within a year or two been brought into the psychological laboratory. Hence we can hardly judge of its merit or promise as a means of affective investigation, though the indications are that it will offer the same difficulties as the other forms of the expressive method.

§ 72. **The Tridimensional Theory of Feeling.** — In 1896, Wundt propounded a theory of feeling that differs radically from the view taken in this book. Pleasantness and unpleasantness, he declared, are not simple affective qualities, but general names for a very large number of different qualities. And even so, the terms pleasant and unpleasant are not adequate as introspective descriptions of our affective experience. That experience is, so to say, tridimensional. Feeling moves, first, between the opposite poles of pleasantness and unpleasantness; secondly, between excitement and depression; and thirdly, between

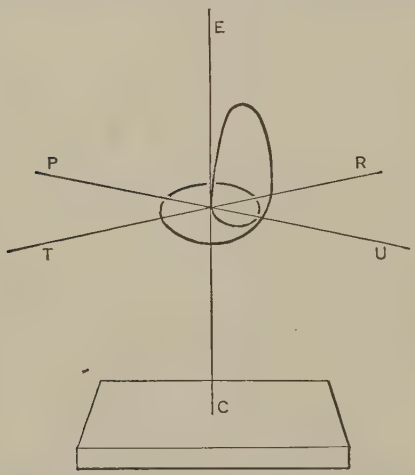


FIG. 38. Diagram representing the course of a typical sense-feeling, according to Wundt's theory. The feeling sets in as a mixture of excitement and unpleasantness, to which tension is soon added. It then drops into the region of pleasantness and calm, takes on a tinge of relaxation, and so ends at the indifference-point from which it started.

tension and relaxation. Excitement and depression, tension and relaxation are, again, general names for a very large number of ultimately different affections. Indeed, the full list of affective qualities, distinguishable under the six headings, is far longer than the total list of sensations.

This theory has found many adherents, and has naturally also aroused a great deal of controversy. It must evidently be met, if our own two-quality view is to be maintained. Let us see, then, what is to be said for and against it.

The first thing to ask about a scientific theory is whether it is logically constructed. Wundt assumes three categories or dimensions of feeling. Pleasantness and unpleasantness depend, he says, upon the intensity of the stimuli that affect us: a moderate amount of stimulation is pleasant, while too much or too little is unpleasant. Excitement and depression depend, similarly, upon the quality of stimulus. Finally, tension and relaxation depend upon time, upon the temporal aspects of stimulus; as we wait and expect, we become tense, and when the event happens, we relax. In other words, our sensory experience varies in degree, varies in kind, and varies in time: and every such variation corresponds to a distinct category of affection. But now the critical question arises: Does not our sensory experience also vary in space? Do not spatial perceptions and spatial ideas bulk as large in consciousness as intensive or qualitative or spatial? Is not the world of space as native and as important to us as the world of time? And if this is the case, as it undoubtedly is, then Wundt's theory is illogical. There should be four affective dimensions, not three; and the fourth sort of

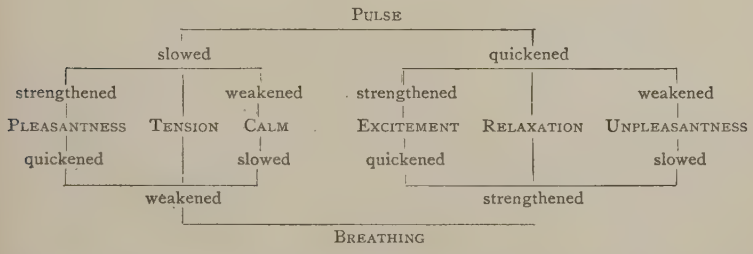
feelings should depend upon the spatial aspects of stimulus. The objection is, indeed, more than logical; it is also psychological; for a view of feeling which ignores the part played by space in our mental life must be psychologically inadequate.

Now consider a second point. Pleasantness and unpleasantness are opposite, in name and in nature. But relaxation is hardly, in the same way, the opposite of tension; relaxation is rather the minimum, the zero point, of tension. And what is the opposite of excitement? Sometimes Wundt says depression; sometimes calm; sometimes arrest. But these three feelings are surely different: to feel depressed is not the same thing as to feel calmed down, and to feel calmed down is not the same thing as to feel checked or baffled. Logically, the pairs excitement-depression and tension-relaxation are not of the same order as the pair pleasantness-unpleasantness. And again the objection is more than logical; for the direct opposition that is felt in pleasantness-unpleasantness cannot be felt in the other two cases.

It appears, then, that the new theory is not logically constructed. More than that, its logical weaknesses point, pretty clearly, to psychological defects. Psychology, however, may now speak for itself: and the first thing it has to say is this, — that excitement and depression, tension and relaxation, are never simple, elementary processes; they are, on the contrary, experiences of some complexity; and they invariably contain organic (especially kinaesthetic) sensations. On the sensory side, they represent — to put it roughly — different muscular attitudes; on the affective side, they may be either pleasant or unpleasant. Pleasurable excitement may be the opposite of depressed mel-

ancholy, or as eager expectancy the opposite of baffled failure; anxious excitement is the opposite of soothing calm. Similarly, a disagreeable tension is the opposite of a pleasant relaxation, but an alert preparedness is the opposite of a despondent unreadiness. The sensory differences may, by the concurrence of pleasantness-unpleasantness, be turned into affective oppositions; without pleasantness-unpleasantness there is no opposition. It is noteworthy that Wundt, in his works upon psychology, strangely neglects the organic sensations: in the present instance, the neglect has led him to transform into simple affections what are, evidently, complexes of organic sensations.

In the last resort, the theory must be put to the test of experiment. Wundt himself appeals to the results of both experimental methods. The method of expression has, we must admit, appeared in a few cases to confirm the theory. Thus, an investigation published in 1907 states the correlation found between the Wundtian categories, on the one hand, and the changes in pulse and breathing, on the other, in the following table:



All that can be said is that results of this neat and clean-cut character are flatly negatived by those of other, equally careful experimenters. We saw in § 71 that the pulse

has often been found to slow (though not to slow and strengthen) in pleasantness, but that this change varies with the sense-organ to which the stimulus is applied. We saw, too, that respiration often grows quick and shallow in pleasantness, but that its changes vary with the individual; it may, for instance, grow quick and deep, and it may grow slow and shallow! It is, plainly, too early to draw any positive inference from the results of the method of expression.

If we turn to the method of impression, we find results that tell very strongly against the theory. The stimuli—colours or tones or rhythms—are presented in pairs, in the usual way, and the observers are asked to say, in successive series, which of the two is the more pleasant or unpleasant, the more exciting or depressing, the more straining or relaxing. Now, in the first place, the affective curves for excitement, depression, tension and relaxation are always identical with the curve of pleasantness or unpleasantness; there is no special curve, no novel distribution

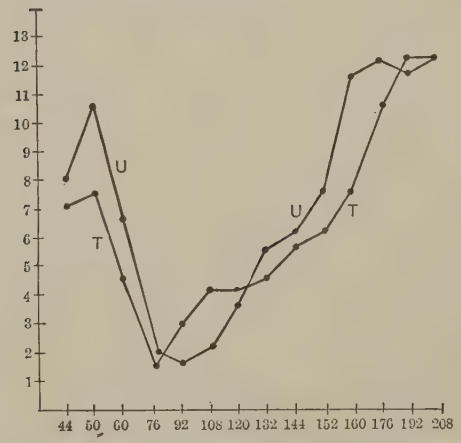


FIG. 39. Curves of tension (*T*) and of unpleasantness (*U*), showing that the distribution of judgments under the two headings is practically identical. The stimuli were metronome-beats, given at the rates marked along the horizontal line: 44, 50, . . . in the 1 min. The figures on the vertical line denote the number of choices. It will be seen that the least straining were also the least unpleasant stimuli (76, 92), while the most straining were also the most unpleasant (176, 192, 208).

of preferences, corresponding to excitement, etc. Moreover, the different observers put different interpretations upon these terms: if excitement is taken to mean anxious, nervous excitement, its curve agrees with that of unpleasantness; if it is taken to mean eager, expectant excitement, its curve agrees with that of pleasantness. Similarly, if relaxation is taken to mean comfortable restfulness, its curve is that of pleasantness; if it is taken to mean a despondent giving-up, the curve is that of unpleasantness. Objectively, then, in the course of the curves, there is no evidence of new affective dimensions. And secondly, the introspective report of the observers bears out the objective testimony of the curves; excitement and depression, tension and relaxation are always described as complexes of affection (pleasantness-unpleasantness) and organic sensation. What Wundt has to appeal to is nothing more than casual observation of his own; systematic work by the method of paired comparisons has brought no support to his theory. —

So far, we have simply discussed the three main categories or dimensions of feeling. Wundt, it will be remembered, believes that each one of these dimensions comprises a very large number of ultimate affective qualities. We need concern ourselves only with pleasantness and unpleasantness: but we have still to ask whether there is just one sort of pleasantness and one of unpleasantness, or whether there are varieties of agreeableness under the common name of pleasantness, and varieties of disagreeableness under the common name of unpleasantness.

To this question no final answer can be given. The experimental evidence is both scanty and conflicting. A distinction has been drawn, for instance, between the local-

ised pleasantness of a taste, while the sweet substance is in the mouth, and the diffused pleasantness which remains after it has been swallowed. But in the former case consciousness as a whole is narrowed down to a taste-in-the-mouth (§ 69); and the pleasantness is diffused over that narrow consciousness just as, a moment later, it is diffused over a wider consciousness. Moreover, if the observer is told that he may keep the sweet substance in the mouth, as a matter of convenience, but that he is to observe his feeling as soon as he has tasted, — that he is not to hold his attention continuously upon the course of the sensation of taste, — then he reports that the pleasantness is not localised, but spread broadly over everything. And in any case a localised pleasantness need not differ in kind, in quality, from a diffused pleasantness: that difference has still to be proved. The writer has never found, in his own experience, the qualitative differences that Wundt assumes.

Wundt has on more than one occasion called attention, on behalf of his theory, to the feeling of the chord *c-e-g*. Tones, he says, usually bring out affective processes of the two dimensions pleasantness-unpleasantness and excitement-depression. Each one of the three tones *c*, *e*, *g* will therefore give rise to what we may call a quiet cheerfulness of a specific kind: there will be six affections for the three sensations. But, further, a simple affective quality may accompany a complex of sensations: so that we have three more affections for the complexes *c-e*, *e-g*, *c-g*, and yet another — probably the dominant — affection for the whole chord *c-e-g*. In sum, our affective experience of the chord is the resultant of no less than ten affective qualities. In the writer's introspection there is no evidence of this compounding; the sense-feeling entirely lacks the depth, the richness, the solidity that on the theory it ought to possess; the affective character of the chord seems to be adequately described in the terms 'slightly pleasant,' 'moderately agreeable.' —

In spite of all that can be urged against this and similar theories

of a plurality of affective qualities, the alternative position may still seem barren and repellent. We have been so carefully taught to distinguish the higher from the lower pleasures that the denial of any differences of kind, within pleasantness and within unpleasantness, may come with something of a shock. Is it really true that the pleasure of a good dinner is identical with the pleasure of a good action?

Well! remember always that affective psychology is in the trial stage, and that no one can dogmatise on the question. But in the writer's belief it is true. A good dinner and a good action seem to him to differ — not in their pleasantness: that is precisely where they are alike; but — in practically everything else. The good dinner and the good action have been set apart, in popular psychology, by reference to their one point of resemblance. And if this sounds paradoxical, remember again that popular psychology does not analyse. For it, the good dinner and the good action are both matters of feeling, of enjoyment or satisfaction: if, then, they differ, they must differ as feelings: and if they differ as feelings, they must differ as the lower pleasure differs from the higher. The conclusion follows only if you accept an uncritical use of the term feeling, and shirk the task of psychological analysis.

§ 73. **The Dependence of Affection upon Stimulus.** — When we were discussing the different kinds of sensation, we sought in every instance to connect the mental with the physical, to refer a certain attribute of sensation to a certain phase or aspect of stimulus. We found, for example, in § 15, that in general the wave-length, wave-amplitude and wave-form of light correspond to the three qualitative attributes of visual sensation, — hue, tint and chroma; although, in detail, the relation between visual stimulus and visual sensation is very far from simple. We have now to attack the same problem in regard to affection. How are pleasantness and unpleasantness related to the various aspects of stimulus?

The question has been much debated, and the answer is exceedingly difficult. If we could not discover a simple, one-to-one correlation in the case of sensation, we can hardly expect to discover it in the case of affection. For we have taken the position — not, it is true, as demonstrated beyond the reach of doubt, but at any rate as the most tenable in the present state of psychology — that there are but two qualities of affection, and that these are incompatible in consciousness. Hence the affection of any given moment is, so to say, the algebraical sum of the affections attaching to all the various sensory processes that constitute our mind at that moment. Or rather, since consciousness is not a mosaic but a system,[1] the affection of any given moment depends upon the interplay or concurrence of sensory processes that are combined in a certain conscious pattern; affection depends, primarily, upon the total disposition or arrangement of consciousness.

Might we not, however, secure an indifferent frame of mind in our observer, and then subject him to stimuli of different qualities, of different durations, of different degrees of intensity, — and note how he is affected by them? Truly, if the indifferent frame of mind would remain indifferent. But the action of the stimulus may be sufficient to shake consciousness out of its indifference, and to set up a wholly new, and perhaps highly affective, conscious pattern: precisely as the very slightest touch upon the kaleidoscope will throw the bits of coloured glass into a new arrangement. We have seen (§ 60) that even a weak stimulus arouses a general bodily reverberation; and in the same way a single incoming stimulus may touch off a complete consciousness, so that its own special affective value is

[1] Cf. the discussion of the taste-blends, p. 134 above.

masked and obscured by the affective resultant of the system.

Nevertheless, so much seems clear: that affection depends less upon the several and separate attributes of stimulus than upon their combination. We noted in § 12 the existence of sensory attributes of the second order; and we gave as illustration the aggressiveness or insistence or importunity of sensation that results from the connection of clearness with intensity, or clearness with quality, or what not. It is this secondary attribute of aggressiveness that appears to determine the arousal of affection; and the higher degrees of it appear to arouse unpleasantness, the lower degrees pleasantness. We can hardly with confidence say more; and in saying this we must remember that affection is extremely liable to adaptation, so that the insistence of a particular stimulus may quickly disappear.

Wundt connects the dimension of pleasantness-unpleasantness with the intensity of our experience (§ 72); and it must be admitted that intensity is one of the commonest and one of the most dominant factors in what we have termed insistence. But there are qualities that are similarly aggressive: bitter, for instance, or tickling. It is hardly possible to make a strict comparison between the intensities of different qualities; but it will probably be agreed that bitter is unpleasant at an intensity at which sweet is still indifferent, and tickling unpleasant at an intensity at which pressure is indifferent. And in general, sensations of taste and smell seem to be more insistent, and are certainly more affective, than sensations of sight and hearing.

There is some little evidence that affection, on its intensive side, obeys Weber's Law (§ 66). While the lower degrees of insistence are pleasant, and the higher degrees unpleasant, a progressive increase of insistence within either region of the scale will give us, of course, an increasing pleasantness or an increasing

unpleasantness. Now we have seen that intensity of stimulus is oftentimes the dominant factor in insistence. Where this is the case, it seems probable that, if the intensity of affection is to progress by equal steps or intervals, then the intensity of stimulus must increase by relatively equal amounts. At any rate, it is true as a general rule that what gives us pleasure or displeasure is roughly proportional to our income, our age and status, our ambition, our standard of comfort. If I am starting a library with a hundred volumes, and a single book is given me, I am as pleased — other things being equal — as I should be by the addition of ten volumes to a library of a thousand. The stamp which completes the set in the schoolboy's album gives him as much pleasure as the acquisition of the last farm which completes the ring-fence gives the wealthy landed proprietor. All these things sadly need experimental confirmation; but there seems no reason why affective intensity should not, and there seems to be some evidence that in fact it does, follow the same law as the intensity of sensation.

§ 74. **The Bodily Conditions of Affection.** — If we know but little of the affective processes themselves, we know still less about their bodily conditions. The suggestions that follow are, therefore, entirely hypothetical.

It is natural to suppose that the material of consciousness, the stuff out of which mind is made, was originally homogeneous, all of a piece: so that sensations and affections are simply different species of the same genus. We have seen, indeed, that there is positive evidence for this view; there are fundamental resemblances between the two elementary processes, which point to their derivation from a common mental ancestor. If, then, we adopt it as a working hypothesis, the affections appear — not exactly as undeveloped sensations, for an undeveloped sensation is still a sensation — but at any rate as mental processes of the same general kind as sensations, and as mental pro-

cesses that might, in more favourable circumstances, have developed into sensations. The writer hazards the guess that the peripheral organs of affection are the free afferent nerve-endings — what are ordinarily called the free sensory nerve-endings — distributed through the various tissues of the body; and he takes these free endings to represent a lower level of organic development than the specialised receptive organs, or organs of sense. Had mental development been carried further, pleasantness and unpleasantness might have become sensations: in all likelihood would have been differentiated, each of them, into a number of sensory qualities. Had our physical evolution been carried further, we might have had a corresponding increase in the number of internal sensations.

It was said in § 42 that the free nerve-endings of the epidermis are probably to be regarded as the terminal organs of pain. If this hypothesis is correct, we might perhaps assume, as some psychologists do, that there is a close genetic kinship between the sensation of pain and unpleasurable affection. Pain would then appear as a specialised sensory derivative from unpleasantness, and would still retain an end-organ of the affective type.

On the other hand, we have to remember that the cutaneous pain-sense has three qualities, itch, prick, and pain proper, and that these qualities are by no means necessarily unpleasant. Intensive pains are unpleasant; but so are bitter tastes, and so are rank and foul and nauseous odours. Besides, we know very little about the cutaneous sense-organs, aside from pressure, and we know nothing at all of the organs of the dull, deep-seated pain that seems to be different from the bright and thrilling pain at the surface of the body (§§ 41, 56). The pains proceeding from muscular tissue and from the peritoneum probably have specialised organs. On the whole, therefore, it is best to leave pain out of account. If the free endings of the epidermis are not organs of pain, the physiological evidence for the connection of pain with

unpleasantness falls to the ground. If they are, it is still possible that their exposed position and consequent liability to injury allow them to function as sense-organs, while they are replaced in the interior of the body by more highly specialised structures; or it is possible that they have become adapted, in some unknown way, to the reception of sensory stimuli. No opinion can be more than a conjecture.

This theory of the bodily conditions of affection explains, first, the lack of the attribute of clearness. Affective processes are processes whose development has been arrested; they have not attained, and now they never can attain, to clear consciousness. Affective experience is the obscure, indiscriminable correlate of a medley of widely diffused nervous excitations. The theory explains, secondly, the movement of affective processes between opposites; for the nervous excitations will vary with the tone of the bodily systems in which they are set up, and that tone can itself vary only in two opposite ways. It explains, thirdly, the introspective resemblance of affection to certain organic sensations; genetically, the two sets of processes are near akin, and it is natural that they should be alike in experience. And it explains, fourthly, the apathy or lack of feeling that comes with visceral anaesthesia (§ 56); for if the specialised nerve-terminals, the sense-organs of the viscera are paralysed, it is to be expected that the unspecialised free endings, occurring in the same tissues, should share their fate. Finally, the theory is non-committal on the questions of mixed feeling and of a differentiation of qualities within pleasantness-unpleasantness. It thus serves well enough for the present state of our psychological knowledge. It is, nevertheless, simply a guess.

Many other guesses have been made with regard to the bodily conditions of affection, both peripheral and central. Under the latter heading it has been conjectured, for instance, that the affections are indices of the state of nutrition of the cerebral cortex; that they are symptoms of the readiness of motor discharge; and that they are connected with the activity of a special cortical centre. Each one of these hypotheses has a certain plausibility, but none is within measurable distance of proof. —

When physiology leaves us in this perplexity, it is but natural that we should make appeal to the wider science of biology. Can biology help us to a psychology of feeling? Well! a great deal has been written about the biological significance of pleasantness and unpleasantness. The pleasurable, we are told, corresponds to the useful, and the disagreeable to the harmful; pleasant experiences are good and unpleasant experiences are bad for the organism. And this means that pleasantness is felt when the activity of a bodily organ is in balance, outgo of energy equalling intake of nourishment; and that unpleasantness is felt when the organ is out of balance, either overworked or overnourished. But, first, the general law of correlation, pleasant-useful and unpleasant-harmful, cannot be made out: there are gross and obvious exceptions. Moreover, if it could be made out, it would not aid our psychology; for useful and harmful mean nothing until they are translated into psychological and physiological terms; and as soon as the translation has been made, we can dispense with biology altogether. Secondly, the theories of organic balance are as conjectural as the rest, and are very difficult to apply in detail. It is hardly worth while, therefore, to devote further space to biological considerations.

References for Further Reading

§§ 68–74. Wundt's tridimensional theory is set forth in his *Outlines of Psychology*, 1907; or, at greater length, in the *Grundzüge der physiologischen Psychologie*, ii., 1902, 263. For a theory which identifies affection with sensation, see C. Stumpf, *Ueber Gefühlsempfindungen*, in the *Zeitschrift f. Psychologie*, xliv., 1906, 1. A critique of these theories, and a discussion of the differences between sensation and affection, will

be found in the author's *Lectures on the Elementary Psychology of Feeling and Attention*, 1908, Lectures II.–IV.

For the method of impression, see S. P. Hayes, *A Study of the Affective Qualities*, in *American Journal of Psychology*, xvii., 1906, 358. For the method of expression, see J. R. Angell and H. B. Thompson, *A Study of the Relations between Certain Organic Processes and Consciousness*, in *Psychological Review*, vi., 1899, 32; P. Zoneff and E. Meumann, *Ueber Begleiterscheinungen psychischer Vorgänge in Athem und Puls*, in Wundt's *Philosophische Studien*, xviii., 1903, 1; M. Kelchner, *Die Abhängigkeit der Atem- und Pulsveränderung vom Reiz und vom Gefühl*, in *Archiv f. d. gesamte Psychologie*, v., 1905, 1; N. Alechsieff, *Die Grundformen der Gefühle*, in Wundt's *Psychologische Studien*, iii., 1907, 156; F. Peterson and C. G. Jung, *Psycho-Physical Investigations with the Galvanometer and Pneumograph in Normal and Insane Individuals*, in *Brain*, xxx., 1907, 153.

On the biological significance of feeling, see H. Spencer, *Principles of Psychology*, i., 1881, pt. ii., ch. ix.; H. Ebbinghaus, *Grundzüge der Psychologie*, i., 1905, 568; D. C. Nadejde, *Die biologische Theorie der Lust und Unlust*, i., 1908. A genetic theory of feeling, in some respects akin to that of the text, but differing from it on important points, is worked out by J. M. Baldwin, *Mental Development in the Child and the Race: Methods and Processes*, 1895, 481 ff.; 1906, 457 ff.

ATTENTION

§ 75. **The Attentive Consciousness.** — The word 'attention,' like the word 'feeling,' has been employed in the history of psychology to denote very different things. Attention has been regarded, at various times, as a peculiar power or capacity, the faculty of concentration, the ability to restrict at will the field of consciousness: as a peculiar form of mental activity, an effort that one puts forth or an initiative that one takes, radically different from the passivity with which impressions are received: as a state of the whole consciousness, a state of clear apprehension and of effective thought: as a feeling or emotion: and, finally, as a complex of sensations, and more especially of kinaesthetic sensations.

It is plain that not all these views can be correct, though every one of them can find a certain support in the facts of observation. When I am so deeply sunk in a scientific problem that I forget my headache, or fail to hear the dinner bell, I seem, pretty clearly, to be exercising the power of concentration. When I force myself to go to work, in face of the temptation to finish an interesting novel, I seem to be exerting a spontaneous activity, to be myself determining my world rather than determined by it. When, again, I wish thoroughly to understand a thing, to make myself master of it, I give it my full attention: attention is, then, that state of consciousness, that degree of being conscious, which guarantees the best

results of mental labour. When I am keenly attending, I am also keenly interested; and interest is a mode of affective experience. Lastly, when I am trying to attend, I invariably find myself frowning, wrinkling my forehead, holding the breath, setting the body in some definite and rigid attitude. All such sets and movements give rise to characteristic complexes of cutaneous and kinaesthetic sensations. Why should not these sensations represent, in psychology, what we popularly call attention?

The appeal lies to experimental introspection: and our rule must be here as it has been elsewhere, that if the experimental results come into conflict with our preconceived opinions, the opinions are to be given up. But before we enter upon the experimental study of attention, let us try a bit of straightforward analysis; let us look at a typical attentive consciousness, and see whether our schooling in psychological method helps us to dissect it.

The most promising case will be a case of suddenly aroused attention. Suppose, then, that I am working or reading quietly, and that a telephone message or the entrance of a visitor suddenly demands my attention. The first thing that happens is that there is a redistribution of the entire contents of consciousness. The incoming ideas — my friend's business or the subject of the message — drive to the centre, and everything else, my previous occupation as well as my sensory surroundings, are banished to the outskirts. Consciousness, in attention, is patterned or arranged into focus and margin, foreground and background, centre and periphery. And the difference between the processes at the focus and the processes in the margin is, essentially, a difference of clearness: the central area of consciousness lies clear, the more remote

regions are obscure. In this fact we have, indeed, the key to the whole problem of attention. In the last resort, and in its simplest terms, attention is identical with sensory clearness.

However, we must confine ourselves to observation, and not anticipate. The attentive consciousness is arranged as clear and obscure: so much is evident. Is the consciousness affective? Not necessarily. We may greet our friend with an absorbed interest, with pleasurable concern or with foreboding of unpleasantness; but we may also give him a perfunctory and mechanical attention, which leaves us wholly unaffected. Is the consciousness kinaesthetic? Again, not necessarily. There may be a wide-spread arousal of kinaesthetic sensations, or there may be no sensible change in the muscular system: it depends upon circumstances. So that it appears, even to unaided introspection, that the redistribution of contents into the groups of clear and obscure is the one universal and characteristic feature of the attentive consciousness.

It should hardly be necessary to repeat here that modern psychology knows nothing of a permanent mind, or of faculties or activities or manifestations of such a mind (§ 3). Whatever attention is, it must be described in terms of mental processes, sensations and images and affections, and explained by reference to its physiological conditions. On the other hand, attention offers itself as an admirable touchstone by which the views of modern psychology may be tested. For the whole situation in attention seems, at first sight, to imply a selective and spontaneous mental activity. As I lean back in my chair to think out a psychological problem, I am subject to all sorts of sensory stimuli: the temperature of the room, the pressure of my clothes, the sight of various pieces of furniture, sounds from house and street, scents coming from the room itself or borne in through the open window,

organic excitations of different kinds. I could easily lapse into a reminiscent mood, letting these impressions suggest to me scenes from my past life. I could easily give the rein to my imagination, thinking of the further business of the day, anticipating some event that is to happen in the near or distant future. But I am, in fact, perfectly well able to ignore all distractions, and to devote myself entirely to a single self-chosen idea, — the idea of the problem that awaits solution. It is true, then, that this idea is clear and central, while all the other conscious processes of the moment are obscure and marginal. But it seems to be true, also, that the clearness of the idea is rather a matter of the mind's own concentration than of any character of the idea itself. Besides, I can turn my mind, if I like, to something entirely different; I can give up the problem whenever I feel disposed.

That is the situation in attention, as popular psychology sees it. We must take up the implied challenge, and see whether our own methods can throw any further light upon the question.

§ 76. **The Development of Attention.** — Attention, as the term is popularly understood, has two forms. It may be passive and involuntary, or it may be active and voluntary. These forms are, in fact, characteristic of different stages in mental development; they differ simply in complexity, as earlier and later; they show us the same type of consciousness, but at different periods of our mental growth. It will, however, clear the ground if we now enquire wherein their difference consists, and what are the conditions of their occurrence.

There is, in the first place, an attention that we are compelled to give and are powerless to prevent. Or, to put the same thing in other words, there are impressions that we cannot help attending to, that take consciousness by storm. Intensive stimuli belong to this class. Loud sounds, bright lights, strong tastes and smells, severe

pressures, extreme temperatures, intense pains, — all these are clear in virtue of their intensity; they attract our attention, as the phrase goes, in spite of ourselves; they force their way to the focus of consciousness, whatever the obstacles that they have to overcome. In the same way, there are certain qualities that irresistibly draw the attention: here belong in the writer's experience — though there are very considerable differences between individuals — the taste of bitter, the smell of musk, the sight of yellow. A stimulus that is repeated, again and again, is likely to attract the attention, even if at first it is entirely unremarked. Sudden stimuli, and sudden changes of stimulus, have the same effect. So with movement: the animal or bird that crosses the landscape, the melody that rises and falls to a steady, uniform accompaniment, the insect that crawls over our hand as we lie upon the grass, these things constrain us to attend to them. Novelty, too, arrests the attention. The novel impression is, in psychological terms, the impression that finds no associates when it enters consciousness; that stands alone, in isolation. Such an impression, if it is at all intensive, becomes clear in its own right; it is startling, just as the sudden stimulus is surprising and the moving stimulus is disturbing. And lastly, paradoxical as it sounds, impressions that are in a sense the reverse of novel claim the attention, — impressions that fit in with, are associated to, the present trend of consciousness. The collector, the inventor, the expert are roused to keen attention by stimuli which the rest of the world pass without notice. Most of the striking coincidences in life are accounted for by this law: you are thinking about certain things, and something happens that, because you are thus thinking and because

it is akin to the subject of your thought, captures your attention. What a remarkable coincidence! you cry: but if you had been thinking of something else, there would have been no coincidence. The man in Mr. Kipling's story who wondered, years after the event, how in the world he could have written such good stuff as that, had written under this same law of attention; for when you are thoroughly absorbed in a topic, relevant facts and ideas crowd in upon consciousness; the mind stands wide open to them, while it is fast locked against the irrelevant; and you surpass yourself.

Here, then, is a fairly long list. Intensity, quality, repetition, suddenness, movement, novelty, congruity with the present contents of consciousness, are one and all determinants of attention. When they appear, we have to attend to them, even if we have grounds for attending elsewhere. Attention thus determined, attention at the first stage, is usually termed passive or involuntary attention. Unfortunately, a passive implies an active; and active attention is, as we shall see, a misnomer. Other names have been suggested; but we shall do best to speak simply, in this connection, of primary attention.

It is worth noting that all the members of our list are of a kind to produce a powerful effect upon the nervous system. Intensive stimuli naturally set up intensive nervous excitations; and intensive excitations will not be easily checked or obscured by rival excitations. The qualitative stimuli that compel attention appeal to some peculiar susceptibility of the nervous system. Repeated stimuli have a cumulative influence. Sudden stimuli impinge upon nervous elements that have recently been free from stimulation of their particular kind, that is, upon elements of a high degree of excitability; and it is also probable that the excitations which they arouse suffer less dispersion and diffusion, within the

nervous system, than those set up by the gradual application of stimulus. Moving stimuli affect different nervous elements in quick succession; there is no possibility of fatigue or of sensory adaptation; in a way, therefore, the action of the moving stimulus is cumulative. Novel stimuli, being isolated stimuli, arouse excitations which are not interfered with by others; their action is akin to that of sudden stimuli. As for the effect of congruity with consciousness, it is clear that the more nearly an incoming excitation coincides with an excitation already in progress, the more easily will it make its way within the nervous system, and the more dominant will it become. The novel and the familiar may thus have a similar excitatory value.

Primary attention, however, represents a genetic stage, the earliest stage of attentional development. Hence it is not enough to look at its determinants physiologically; we must also view them biologically. And if we do this, some of them at any rate take on a new significance. Any nervous system will be powerfully impressed by intensive stimuli; any organism that has risen high enough in the scale of evolution to have a consciousness made up in part of ideas, of memories and imaginations, will be powerfully impressed by stimuli that are congruent with those ideas: it is precisely to such stimuli that the gates of the nervous system lie open. But what of novelty and suddenness and movement? These have a special biological meaning: for the new and the sudden and the moving are probable sources of danger, and the creature that failed to attend to them would soon have ceased to exist.

There are, however, many occasions when, so far from the impression's drawing and riveting our attention, it seems that we are holding our attention by main force upon the impression. A problem in geometry does not appeal to us as a thunder-clap does. The thunder-clap takes unquestioned possession of consciousness. The problem has only a divided claim upon us: there is constant temptation to wander away from it and to attend to something else. We continue attending; but we have to

make ourselves attend. In many of the psychological experiments that we have described, the object of attention — an obscure organic sensation, a minute qualitative difference — is something which of itself, so far from attracting notice, would seem to be eminently fitted to escape it. Attention to such an object is usually termed active or voluntary attention; we shall call it secondary attention.

For it is not really active attention, if the adjective implies anything like a special and spontaneous mental activity. It is simply the resultant of a conflict of primary attentions. There are rival claimants for the chief place in consciousness, and the standing-room is limited. So the attention, as we say, is divided; or perhaps it oscillates between the various impressions presented. Secondary attention is attention under difficulties, attention in face of competitors, attention with distraction. But that is its whole secret; it has no novel feature.

Secondary attention is a necessary consequence of a complicated nervous organisation. Let us take an imaginary case: the case of an animal endowed with two sense-organs, an eye and an ear. Suppose that such an animal is exposed, at the same moment, to two different stimuli, a bright light in front of it and a loud sound at its side. It cannot afford to neglect either. Hence it will attend, first, to the stimulus which has the greater attractive force; but then, having attended to that, it will at once turn its attention to the other: and so there will be a seesaw of light and sound at the focus of consciousness, a quick succession of primary attentions. This, as we shall see presently, is not all of the psychological story; but it is the essential point.

Now take a case that lies nearer home. Suppose that you are in your room, preparing for to-morrow's examination, and that you hear an alarm of fire in a neighbouring street. Both ideas, the idea of examination and the idea of fire, are imperative; there is a conflict. The cortex is set in one part for work: and this set-

ting is reinforced by a large number of associated excitations, — the nervous processes corresponding to ideas of the examination mark, the consequences of failure, and so on. The cortex is set in another part for going to the fire: and this setting is similarly reinforced, by the processes corresponding to the ideas of a run in the fresh air, an exciting scene, a possible rescue, and so on. The struggle may last some little time, and its effects may persist for a while after you have made your choice. So long as there is any trace of it, your attention is secondary or 'active' attention.

There is yet a third stage in the development of attention; and this consists in nothing else than a relapse into primary attention. As we work at our problem in geometry, we gradually become interested and absorbed; and presently the problem gains the same forcible hold over us that the thunder-clap has from the moment of its appearance in consciousness. The difficulties have been overcome; the competitors have been vanquished; the distraction has disappeared. There could hardly be a stronger proof of the growth of secondary out of primary attention than this fact, of everyday experience, that secondary attention is continually reverting to the primary form.

We spoke just now of making a choice between work for the examination and going to the fire. The making of a choice means, of course, that the stronger of the two conflicting forces, the rival excitatory processes, has won the day; and the traces of the struggle that persist after the choice has been made mean that the victory has not been absolutely complete. If experiences of the sort are often repeated, so that a habit is set up, — a habit of work or a habit of play, — then the struggle is brief, and secondary attention is quickly replaced by primary.

The mention of habit leads us to a further, and a very important point. This nervous system of ours, which is the scene of

the conflict in secondary attention, has a long evolutionary history. We are not all born equal; we are born with nervous systems that bear upon them a certain hereditary stamp, that already have within them lines of less and lines of greater functional resistance. The poet, we say, is born and not made; and to a certain extent, if the phrase is permitted, we are all of us born and not made. On the other hand, the child's nervous system is exceedingly plastic and impressionable; it is easily moulded by education; so that, to quote another current saying, habit may become second nature. The leanings and aptitudes and predilections that we show in adult life are, then, the resultant of two influences, heredity and education, nature and nurture. Now the important point in the present connection is this: that the side which finally proves to be the stronger, in the struggle of secondary attention, need not necessarily be the consciously stronger. The conflict between working and going to the fire may lead to a victory for work, in spite of the fact that consciousness is more fully occupied by fire-ideas than it is by work-ideas. The nervous system, in virtue of its own bias or leaning, has brought up further reinforcements on the side of work, and these reinforcements have directed or guided consciousness although they are not themselves represented in consciousness.

The guiding influence of nervous bias is not a matter of inference, still less a matter of speculation; it can be demonstrated in the psychological laboratory. Suppose that we are measuring the time required to reply to a spoken word by another word of the same class or kind: to associate dog to cat, table to chair, and so on. The experimenter prepares a long list of words: cat, chair, and so forth. Then he explains to the observer the precise nature of the experiment: I shall call out certain words, he says, and you are to reply, as quickly as you can, with words of the same class; if I say horse, you will mention some other animal, and if I say pen, you will mention something else that has to do with writing. The observer understands, and the experiment begins. Suppose, further, that the experiments have been continued for some days. The experimenter has no need to repeat his explanation at every sitting; the observer takes it for granted that

he is still to reply with a coordinate word. And suppose, finally, that some day, after a week's work, the experimenter interrupts the series, and asks: Are you thinking about what I told you to do? The observer, fearing that he has made some error, and feeling very repentant, will say: No! to tell the truth I had absolutely forgotten all about it; it had gone altogether out of my mind; have I done anything wrong? He had not done anything wrong; but his answer shows that a certain tendency, impressed upon his nervous system by the experimenter's original explanation, has been effective to direct the course of his ideas long after its conscious correlate has disappeared. And what happens here, in the laboratory, happens every day of our lives in the wider experience outside the laboratory.

In summary, then, attention appears in the human mind at three stages of development: as primary attention, determined by various influences that are able to produce a powerful effect upon the nervous system; as secondary attention, during which the centre of consciousness is held by a certain perception or idea, but is held in face of opposition; and lastly as derived primary attention, when this perception or idea has gained an undisputed ascendency over its rivals. The attentive consciousness is at first simple; it then becomes complex, — reaching, indeed, in cases of hesitation and deliberation, a very high degree of complexity; and then it simplifies again. Looking at life in the large, we may say that the period of training or education is a period of secondary attention, and that the following period of achievement and mastery is a period of derived primary attention. Looking at experience more in detail, we see that education itself consists, psychologically, in the alternation of the two attentions: habit is made the basis of further acquisition, and acquisition — gained with pains — passes

in its turn into habit; the cycle recurs, so long as the organism retains its nervous plasticity. Secondary attention thus appears, everywhere, as a stage of transition, of conflict, of waste of nervous energy, though it appears at the same time as the necessary preliminary to a stage of real knowledge.

We may now return to our analytical study of the attentive consciousness. There are three stages of attention, but there is only one type of attentive consciousness; the three stages show differences of complexity, but not differences of kind.

In the meantime, it may prevent a possible misunderstanding if we say, explicitly, that the greater complexity of consciousness in secondary attention does not necessarily mean a greater number of constituent mental processes. The single object of primary attention may be extremely complex; the competing objects of secondary attention may be relatively simple. The complexity, then, is a complexity, not necessarily of conscious contents, but rather of conscious pattern, of the disposition of the contents. In primary attention, consciousness flows smoothly within a definite channel; in secondary attention, its course is zigzag, meandering through various channels. The number of mental processes given in secondary attention may be, and often is, much larger than the number given in primary attention; but the characteristic difference between the two consciousnesses lies elsewhere. Consciousness in primary attention may be represented by a series of parallel straight lines, each standing for some mental process that enjoys its full normal duration; consciousness in secondary attention must be represented by a pattern of shorter and variously directed oblique lines, each standing for some mental process whose progress has been arrested by the advent of a rival.

§ 77. **The Two Levels of Consciousness.** — The rough analysis of § 75 led us to conclude that the attentive

consciousness is always arranged in a dual pattern of clear and obscure, focus and margin. We might represent it by means of two concentric circles, the inner and smaller bounding the region of clearness, or containing what is called the object of attention, and the outer and larger bounding the region of obscurity or of inattention. A more serviceable diagram, however, is one that represents the stream of consciousness as running at two different levels, the higher that of the clear and the lower that of the obscure processes in consciousness. We shall make use of this diagram in what follows.

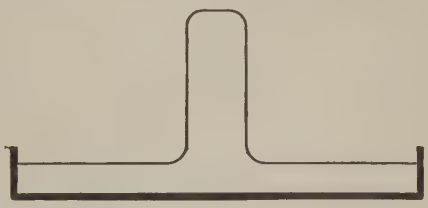


FIG. 40. Diagram of the Attentive Consciousness. The stream of consciousness, outlined by the thin line of the Fig., is supposed to be moving towards you from the plane of the paper; the thick lines represent the neural channel in which the stream is flowing.

Let us begin by making an observation for ourselves. Figure 41 is a puzzle picture; it is a drawing of the left hemisphere of the brain, but it is something else also. Look at it, and try to find what it conceals. While you are searching, the whole drawing is at the upper level of consciousness, and the rest of your experience is at the lower level. Suddenly you find what you are looking for: and what happens? Why, the moment you do so, the picture of the brain drops clean away from the upper level: the concealed outlines stand out with all imaginable clearness, and the form of the brain is no clearer than the feel of the book in your hand. The first two-level consciousness has been replaced by a second, and the drop of the original object of attention from crest to base of the attention-wave is very striking.

In one respect, this observation is not typical. When you have solved the puzzle, you experience a keen satisfaction; and affective processes are not always found in the attentive consciousness. In all other respects, the observation appears to the writer to be typical. The object of attention does not glide, by slow degrees, to the higher level, but rises at a single step; now you are attending to one thing, and now you find yourself attending to another. It should be said, however, that this view is disputed. Some psychologists believe that the attentive consciousness shows,

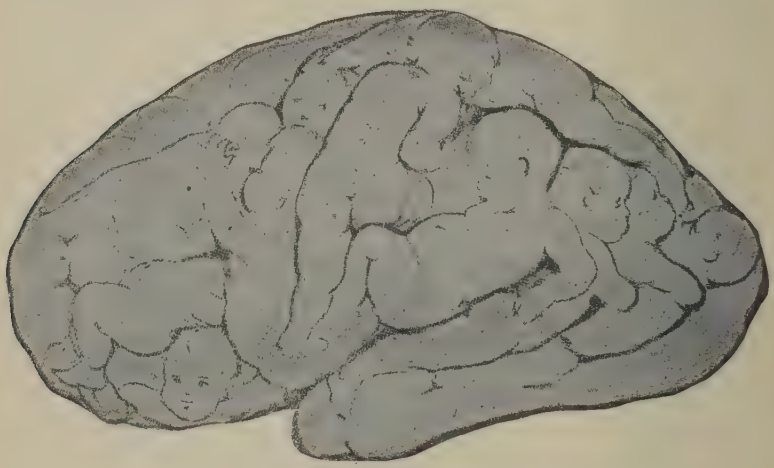


FIG. 41. Drawn by R. Gudden, Frankfurt a. M.

not two different levels, but a single rising and falling slope; they believe, that is, that processes of all possible degrees of clearness may coexist in the same consciousness. Others believe that there are more than two levels, — three, for instance: the levels of attention, of inattention, and of a still deeper, subconscious obscurity. We return to the matter again in § 80.

The main characteristic of the processes at the upper conscious level is their high degree of clearness. We mentioned clearness, in § 12, among the attributes of sensation, and the term carries its meaning with it. A

process is clear or vivid when it is at its best, when it is making the most of itself in experience. Clearness is an intensive attribute, in the sense that it shows degrees of more and less; but it is altogether different from intensity proper. When, for instance, you are listening to a very faint sound, the sensation of noise may be the clearest thing in consciousness, although its intensity is minimal. Indeed, there is no difficulty whatsoever, after a little practice, in distinguishing introspectively between the clearness and the intensity of any given mental process.

It is, however, a much debated question whether clearness and intensity, though distinct attributes of sensation, are not always connected in experience. Does not a rise in clearness mean also a rise in intensity? The very faint sound may be clear, in spite of its weakness: but is it as weak as it would be if it were less clear? In popular phrasing, does not attention intensify its object? We find every possible answer to these questions. Some psychologists believe that change in clearness makes no difference in intensity. Others believe that it makes only an apparent difference. Increase in clearness, they say, means a more independent status in consciousness; and this independence, this freedom from interference, allows the other attributes of sensation to come to their full conscious rights. Intensity thus makes all the effect that it has in it to make; it appears to be increased, whereas in reality it is simply getting — what without clearness it could not get — fair play in consciousness. Others, again, think that clearness does bring with it an increase of intensity; and yet others assert that it means a decrease. In the writer's judgment, the third of these views, that intensity is raised along with clearness, is the most probable.

The belief that change in clearness makes no difference in intensity rests upon facts of everyday observation: your surroundings do not brighten up as you attend to the lamp, the clock does not begin to tick more loudly as you listen to it. But, first, this sort of observation is very unreliable; if you try it for yourself, you will find how far you are from any real comparison of the more clear and the less clear process. And secondly there are facts on the other side: you can hear, with attention, a faint sound that you cannot hear if you do not attend. The next hypothesis, that the change in intensity is only apparent, contains an element of truth; but in so far as it is an attempt to reconcile the first and the third, it will not come into account until the third has been disposed of. The issue lies, therefore, between the third and the fourth views, that attention intensifies and that attention weakens its object; and the test is experiment. There is evidence on both sides; but it appears to the writer that the evidence for weakening is ambiguous, and the evidence for intensification clear and decisive. Suppose, for instance, that two sounds, a weaker and a stronger, are presented to the observer in quick succession; and suppose that he gives full attention to the weaker, but that his attention is diverted from the stronger by some interfering stimulus, for instance, by a strong odour. If he judges that the two sounds are of equal intensity, still more if he judges that the objectively weaker sound is the more intensive of the two, we have an increase of intensity with attention or (what is the same thing) a decrease of intensity with distraction. And this is what happens.

It is not at all surprising that we should find an intimate relation between clearness and intensity; for, as we said in § 76, all the conditions of a high degree of clearness are also conditions for the powerful impression of the nervous system. Nor does the connection of the two attributes affect anything that we have said in §§ 62 ff.: for the intensities which obey Weber's Law are, of course, intensities at maximal clearness.—

It does not seem probable that clearness brings with it any change in extent or duration. Processes, however, that would ordinarily be curtailed, swamped by stronger processes, may — if

they are clear — be followed for a longer time in their course through consciousness, and may thus be apparently lengthened.

We may now interpret Fig. 40 to mean that the processes at the crest of the attention-wave are both clearer and stronger than the processes at the lower level of consciousness. These are the attributes that give the object of attention its special value for memory and imagination and thought.

§ 78. **The Kinaesthetic and the Affective Factors in the Attentive Consciousness.** — We may assume that attention, in its beginnings, was a definitely determined reaction of the whole organism — sensory, affective, motor — upon a single stimulus. The strong or sudden or novel or moving thing was perceived, as sight or sound or touch. It was also, as we have said (§ 76), felt as startling or disturbing or surprising. The affective element in the experience expressed itself in a change of the great bodily functions. At the same time the animal took up an attitude to the stimulus, in the literal sense; faced it, as peering and listening and frightened animals face such stimuli to-day. At this stage, then, the redistribution of the sensory processes in consciousness, the clearing of some and the obscuring of others, was accompanied both by affection, and by kinaesthetic sensations due to internal bodily changes and to muscular attitude.

Secondary attention has its origin in a conflict of primary attentions: in the rivalry of clear perceptions and in the struggle of incompatible motor attitudes. The perceptions may be either pleasant or unpleasant; the motor restlessness will be unpleasant, reflected in an affective uneasiness. We have, now, a survival of this primitive state

of affairs in the effort which always comes with secondary attention. We naturally dislike to work; work of any sort means effort. And effort is itself a sense-feeling, made up of unpleasantness, and of a complex of kinaesthetic and organic sensations. Experiments by the method of expression show that breathing in secondary attention is likely to be inhibited, to become shallow; and there are other bodily changes, correlated in part with the unpleasant affection, in part with the motor restlessness.

As the nervous system developed, image supervened upon sensation, and conflict and rivalry were largely transferred to the field of ideas. Congruity with consciousness now took its place among the determinants of primary attention. There was a radical change in the make-up of consciousness; and one aspect of the change was the weakening of the kinaesthetic and affective factors in attention. The effort that we make when we sit down to work, and the difficulty that we feel for the first few minutes of working, are the direct descendants of the older uneasiness and the older motor restlessness, but they are degenerate descendants, mere echoes of the primitive experiences. So degenerate are they, that some psychologists refuse to regard effort as a sense-feeling: Wundt makes tension a simple affection, and others see in it a new kind of mental element, a conative element or elementary process of will. There is no introspective warrant for either view. Effort, in whatever context we take it, proves to be analysable; it reduces to affection and sensation.

The last stage in this development is given with the passage from secondary to derived primary attention. We began with an affective sensorimotor reaction, the reaction

of the whole organism upon a single stimulus. From that we passed to sensorimotor conflicts, still strongly affective. Then images come in, and separate the sensory from the motor, the reception of stimulus from the movement of response. Henceforward secondary attention may be concerned mainly with the stimulus (receptive attention), or mainly with ideas (elaborative attention), or mainly with movements (executive attention): being secondary attention, being, that is, attention under difficulties, it is always tinged with effort. Finally, secondary passes over into derived primary attention; and when it does, affection and kinaesthetic sensation cease to be necessary factors in the attentive consciousness. Thus, to begin with receptive attention, we may open our morning's mail with keen excitement, or we may attend to it with no change either of affective or of kinaesthetic experience. We may, in elaborative attention, be absorbedly interested in an argument, and allow the body to grow stiff and cramped; or we may take the argument quietly and indifferently. We may, in executive attention, be wholly bent upon the successful performance of a skilled action, and may tire ourselves out in attempting it; or we may make the movements easily and as a matter of course. What we call habitual, mechanical, perfunctory attention involves the two conscious levels of clearness and obscurity, but does not involve either affection or kinaesthesis.

It must be remembered that attention is not something rare and occasional in the mental life, but is the normal state of our consciousnesses. When we charge other persons with inattention, we do not mean that they are, literally, non-attentive; we charge them with inattention to a particular topic; and this inattention means, simply, that they are attending to something else. A

strictly one-level consciousness is certainly abnormal, and probably never occurs in the normal waking state; though it may be realised, or at least approximated, in idiocy (lower level) and in profound hypnosis (upper level). But if attention is thus the rule and not the exception, there is nothing surprising in its becoming a matter of habit, in its leaving us — in both senses of the word — unmoved.

The occurrence of kinaesthetic sensations as the object of attention (for instance, of the executive type) must, of course, be carefully distinguished from their arousal by the motor attitude of the organism in attention. It is the second sort of kinaesthesis whose weakening and disappearance we have traced.

§ 79. **The Experimental Investigation of Attention.** — In taking up the study of sensation, experimental psychology was greatly helped by physics and physiology. Instruments and methods of research were at hand, and needed but little modification to render them serviceable; and a large body of observations, scattered through the physical and physiological journals, could be transferred directly to their proper place in the new science. Hence, from the very outset, the problems of the quality and intensity of sensation were attacked with good hope of success; and although, as is always the case, all sorts of unforeseen difficulties arose, our knowledge of these attributes has steadily advanced.

The experimental study of affection began much later. Here, therefore, we have to make up for lost time. Still, we are entering on the work in the light of all the experience that we have gained with sensation, and physiology has again come to our aid with the instruments needed by the expressive method. Another ten years will probably suffice to lay the foundations of a stable affective psychology.

Interest in attention goes further back. As soon as the work upon sensation had been fairly started, experimental psychology turned to the investigation of attention. Here, however, it found no outside assistance; physics and physiology had nothing to offer; there was only a popular psychology to build upon. And so the experimentalists made the mistake — natural, almost inevitable, but still a mistake — of grappling with the total attentive consciousness, all at once, instead of beginning with a psychology of clearness, and developing it on the lines of the psychology of intensity and quality. The consequence is that we know less about attention than we should; a good many of the earlier studies have to be done over again, little bit by bit; the problems have to be split up, and made more manageable. Even so, the experimenter of to-day is hampered by the past; he wishes to keep all the results of previous work that can be kept, and therefore, while he makes his problems as narrow and definite as possible, he shapes them in accordance with psychological tradition. But science must set out from the simple, and move gradually to the complex. A total consciousness is the most complicated thing that psychology has to deal with, and its treatment should come last of all. If we want to understand attention, we must begin at the other end, with an exhaustive study of the attribute of sensory clearness.

A few names and dates may be given in illustration. The psychology of intensity is connected especially with the name of Fechner, who published his *Elemente der Psychophysik* in 1860. The psychology of quality is connected, similarly, with the name of Helmholtz, who published the *Handbuch der physiologischen Optik* in 1856–1867, and the *Zur Lehre von den Tonempfindungen*

in 1863. The experimental study of attention may be dated from 1861, when Wundt (*Beiträge zur Theorie der Sinneswahrnehmung*, 1862 ; *Human and Animal Psychology*, 1896, 270) began the series of researches that have culminated in his doctrine of apperception. The experimental study of affection may be dated, in the same rough way, from the appearance in 1892 of A. Lehmann's *Die Hauptgesetze des menschlichen Gefühlslebens*, which took the prize offered by the Royal Danish Academy of Sciences in 1887 for a scientific work upon the feelings.

In the meantime, a glance at Fig. 40 will show that the attentive consciousness sets a number of experimental problems. There is, for instance, the problem of the area of the attentive-wave, or of the range of attention. The question: How many things can we attend to at once? has often been asked, and has been very variously answered. A busy man will tell you, if you interrupt him, that he can't possibly attend to more than one thing at a time. On the other hand, it is related that Julius Caesar and the first Napoleon could carry in their heads the topics of a dozen despatches, and could dictate them without confusion to as many secretaries. There is also the problem of the length of the attentive-wave, or of the duration of attention. For how long a time can attention be maintained? In everyday experience, the object of attention is continually changing. Does attention lapse, as we pass from object to object? Then there is the problem of the height of the attention-wave, or of the degree of attention. How many different degrees can be distinguished, and how can they be measured? We speak roughly of close or rapt or absorbed or concentrated attention, and we contrast it with wandering or fitful or divided attention. But this, after all, is much like saying that our sensations of

light are black, white and grey; we want a more exact statement, and if possible a statement in numerical terms. The present condition of our knowledge, on these and kindred topics, is briefly set forth in the following sections.

§ 80. **The Range of Attention.** — Our problem is to determine how many impressions can be attended to together, without decrease of the clearness which each one of them would possess if the attention were directed to it alone. We can approach the problem in two ways, by a simultaneous and a successive method. Thus, we may present a number of stimuli to a sense-organ at the same time, and gradually add to them, until it becomes impossible to attend to all at once. In the case of sight, for instance, we may show the observer a number of dots, lines, letters, numerals, simple geometrical figures, bands of colour, etc., laid upon the same background. Or we may give the stimuli in succession, gradually increasing their number till the point is reached at which the first drops into obscurity as the last is given. This method answers best with auditory stimuli. In both forms of the experiment, the object of enquiry is the same; we wish to determine the limit of complexity at which the attention becomes unable to cope with the stimuli offered to a particular sense-organ. And in both the same result is reached; the attention is able to embrace six, simultaneous or successive impressions, of a relatively simple kind and of unitary character.

Method of Simultaneous Stimuli. — Experiments are made by means of the tachistoscope, an instrument which, as its name implies, permits the exposure of a limited field for very brief periods of time. The time of exposure must be short, since

otherwise the eye may sweep rapidly over the stimuli, leaving some to be remembered while others are directly attended to; in this case we should be dealing, not with the grasp of a single attention, but with a series of attentions. And the exposed field must be so small that it is readily taken in by the eye at a glance, without eye-movement, since otherwise the obscurity of the outlying stimuli may be a matter, not of the limit of attention, but of indirect vision (§ 20).

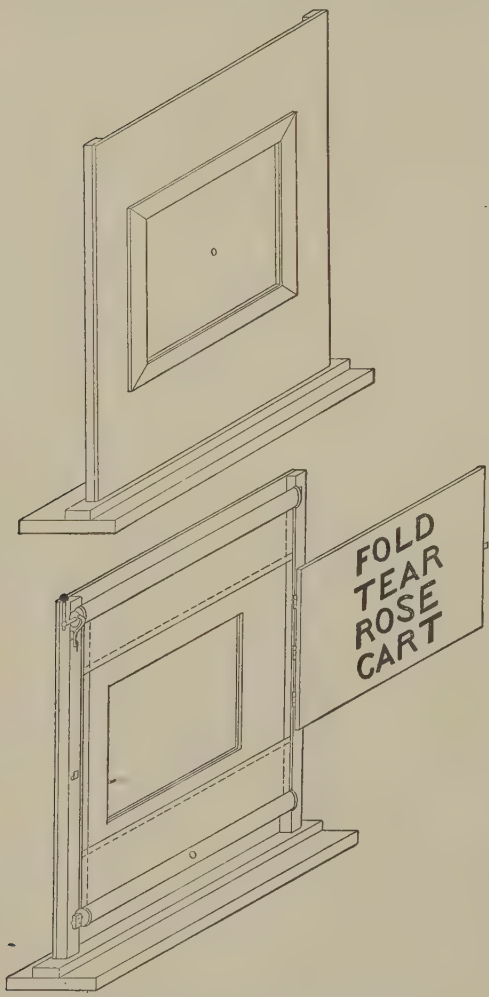


FIG. 42. Demonstrational Tachistoscope. A black curtain, mounted on strong spring rollers, is stretched behind a square opening in a black wooden screen. The upper Fig. (front) shows the curtain and the white fixation-mark. The lower Fig. (back) has the card-carrier thrown back to show the square opening in the curtain itself.

If letters are employed as stimuli, they must form a meaningless series, such as *RKZT*. It has been found that a familiar word of three or four letters can be apprehended by the attention as if it were a single letter or geometrical figure; it is attended to, not as a series of letters, but as a single impression.

For the same reason, the attention can deal with numerals better than with disconnected letters; any combination of numerals means something, makes sense.

The maximal range of the visual attention, for a practised observer, comprises six impressions; individual ranges differ between the limits of four and six. Experiments with simultaneous impressions of touch have given a like result; a practised observer is able to localise six scattered points correctly. This observation, however, needs confirmation.[1]

Method of Successive Stimuli. — The running weight upon the tongue of a bell-metronome is set for two hundred beats in the minute. The experimenter marks off two series of beats by sounding the bell simultaneously with the first beat of each series. The observer is required to say whether the two successive series are equal or unequal. He must not count, of course; counting would mean that a separate attention was given to every beat.

Accurate judgment is impossible in the case of series which consist of more than six impressions. And if the metronome could be run very slowly, — say, at fifteen in the minute, — the range of attention would be no more than six single beats. But just as in the previous experiment a short word was equivalent, for the attention, to a single letter, so here a group of beats may, under certain conditions, be equivalent for the attention to a single beat. As the rate of the metronome is increased, we cannot help reading into the succession of strokes a more or less complicated rhythm. At first, with rates that are still fairly slow, the beats group themselves into twos or threes, and the attention is still adequate to six impressions, — six rhythmical units of two

[1] It is natural to recall, in this connection, that the point-characters of the Braille and the New York Point alphabets for the blind both alike ring the changes on a single symmetrical arrangement of six dots; and it is tempting to suppose that the limit of six was set by the limit of the range of tactual attention. But, as a matter of fact, the suggestion of the sixfold unit came from visual memory of the double-six domino: no preliminary experiments were made on touch. It also seems certain that blind readers do not, in general, distinguish the separate dots, but apprehend the total form of the letter, as if the dotted lines were continuous.

beats (twelve beats in all) or six rhythmical units of three beats (eighteen beats in all). Finally, at the rate specified above, the attention can cover only five impressions, five rhythmical units: but these may now consist of eight or even, it is said, of twenty-four single beats; so that the series of five impressions consists of forty or even of one hundred and twenty metronome strokes. The groups of eight and of twenty-four are apprehended as units, akin to the short word of the previous method.

This result agrees very well with the canons of musical and poetical practice. The musical phrase never contains more than six measures, the poetical verse or line never contains more than six feet; a seven-measured phrase or a seven-footed line falls to pieces, ceases to be unitary. And the rhythmical wholes of a higher order, the period in music and the stanza or strophe in poetry, never contain more than five phrases or verses; as a rule, neither contains more than four.

Minor Differences of Clearness at the Upper Conscious Level. — We have seen that the short word, the complexes of geometrical figures, and the rhythmical unit have, for the attention, the value of single impressions. Since they stand at the upper level of consciousness, their component parts are all clear. But they are by no means equally clear. Think, for instance, of a simple rhythmical unit, such as we might read, in music, *ONE* — and two — and *three* — and four — and. Here the first member is the strongest and clearest, the fifth stands next in order, and the second, fourth, sixth and eighth are relatively weak and obscure. This means that the upper level of the attentive consciousness is, as a rule, wrinkled into smaller waves, and not smooth, as it is drawn in Fig. 40. There are degrees of clearness within the clear. And this, again, may account for the belief, held by some psychologists (§ 77), that all possible degrees of clearness may coexist in the same consciousness.

Whether there are, in the same way, degrees of obscurity within the obscure, wrinkles or wavelets at the lower level of Fig. 40, is still uncertain. In any event, these minor waves at the two levels are quite shallow, and cannot mask the gross difference between the levels themselves.

§ 81. **The Duration of Attention.** — If, ten years ago, an experimental psychologist had been asked for how long a time a single wave of attention could last, he would have replied without hesitation: For a few seconds only. Many experiments have been made, he would have said, and all have led to the same result: that attention is not persistent, but intermittent, — rising and falling, waxing and waning, at very short intervals. If you attend as closely as you can to a simple sense-impression, it does not remain clear, but becomes alternately clear and obscure; the attention fluctuates.

If the same question is asked to-day, the reply must be that, while we know a good deal more about the general subject, we do not know how long attention may continue. It may, undoubtedly, remain constant for two or three minutes. In the writer's judgment, it may remain constant for much longer periods.

It has been customary to work with minimal stimuli, — stimuli so small, or so weak, or so little different from their surroundings, that the least slip of attention, the slightest loss of clearness, will mean the disappearance of their sensations from consciousness; for it is far easier to say that we do or do not hear or see something than it is to be sure that what we see or hear has grown more or less clear. Visual, auditory and cutaneous stimuli have been employed: light and colour, tone and noise, mechanical pressure and the interrupted current. You may picture the experiment by imagining yourself as seated at a table, gazing fixedly at a little disc of light grey on a white ground, or listening with all your ears to the faint hissing of a stream of fine sand, while your hand rests upon a pneumatic key, the pressure of which records the moments of disappearance and reappearance of the sensation upon a kymograph in the next room.

For the sensation does, at least in certain cases, disappear and reappear. The earlier experimenters found this fluctuation in all

three of the sense-departments mentioned, and they found it with images as well as with sensations. They accordingly assumed that it must be due to some common factor, and — naturally enough — ascribed it to the intermittence of attention. There were, it is true, objectors, who pointed out that the attention need not be involved. The eye has a mechanism of accommodation in the lens and its muscular attachments, and the ear has a similar mechanism in the muscle known as the *tensor tympani*, which pulls upon the drum-skin : why might not the intermittence of the minimal sensation be due to peripheral changes, to shifts of accommodation? But the reply seemed conclusive : visual fluctuation was observed during temporary paralysis of the muscles of accommodation, and even in the case of aphacic subjects, patients whose eyes had lost the lens; and auditory fluctuation was proved to occur despite the lack of a tympanic membrane. The theory of an intermittent attention had apparently won the day.

FIG. 43. Masson's Disc. The broken radius, painted black on white, gives rise, when the disc is rotated, to a series of grey rings, which grow lighter and lighter towards the periphery. The observer follows the grey out from the centre, and steadily fixates some point upon the outermost ring that he can distinguish.

Nevertheless, the peripheral theory would not down. New experiments were made on touch ; and it was found that the minimal sensations set up by tiny weights and by a weak electric current do not fluctuate at all. If there is no outside disturbance, no itching or tingling or movement of the skin, the sensations run their course without interruption, until they fade out by adaptation. During these experiments it was observed that a steady attention might be kept up for at least two or three minutes. New experiments were also made on vision ; and it was found that visual sensations, too, tend to fade out into their background by adaptation, but that the course of adaptation in their case is interrupted,

— interrupted by involuntary eye-movement. The involuntary movements were timed, their direction was noted, and their extent was measured: in all three respects there was agreement between occurrence of movement and disappearance of sensation. Reappearance is due in part to the recovery of the retinal elements during movement, in part to the faulty adjustment of the eye; the eyeball does not return after movement to precisely the position that it had before movement, and the stimulus may therefore affect retinal elements which have not as yet been exposed to adaptation. It was found, further, that the negative after-image, the after-effect of local adaptation (§ 18), behaves in precisely the same way as the primary sensation; intrinsically, the course of the after-image is continuous, but it is interrupted when and in so far as eye-movement takes place.

So far, then, there is no need to invoke the attention, in order to explain fluctuation; we must suppose that the older observers were misled by preconceived opinion, or perhaps fell into errors of technique. But what, now, of tone and noise? Well, the fluctuation of tone and noise is still under discussion. Some observers have failed to get fluctuation with either; others get fluctuation with both. The reason for this difference of result may, possibly, be physical: it is extraordinarily difficult to maintain either a tone or a noise at absolutely uniform intensity; and a very slight change in objective intensity will, of course, bring a faint tone or noise to complete disappearance.

Here we are, for the present, at a standstill. We do not know how long a single wave of attention, carrying a single sensation of sight or sound or touch, may continue. Nor do we know for how long a steady level of attention may be maintained under the conditions of everyday life, where the object of attention is constantly changing. The single wave may continue at least for two or three minutes; the writer would not be surprised if it should turn out that the steady level may be maintained for two or three hours.

§ 82. **The Degree of Attention.** — The measurement of attention is one of the most pressing problems in experi-

mental psychology. If we could measure a man's capacity of attention, and could discover at any moment what proportion of that capacity he was using: if, that is, we could determine the greatest possible height of the attention-wave, in Fig. 40, and could find out its actual height in the case before us: then we should have a result of the greatest scientific importance and of the utmost practical value. Many experiments have been made, but the problem is still far from solution.

One difficulty has grown out of the popular use of the word attention. When the term is used without qualification, we naturally think of it as secondary attention; we think of the attention that the teacher enjoins on the pupil, of the effort of attention. Primary attention, whether original or derived, is so natural an attitude, so much a matter of course, that we hardly notice it: at most, when we see it in others, we say that so-and-so is absent-minded, or is in a brown study. This mistake, of identifying attention with secondary attention, is especially natural to the man of science, who is always puzzling and searching. So it comes about that psychologists have proposed to measure the degree of attention by measuring the degree of effort which accompanies it. We can measure sensation; kinaesthetic sensations indicate the degree of attention; hence, if we measure them, we have also measured attention.

The argument is fallacious, for the simple reason that the higher degrees of attention do not involve effort. When we have reached the stage of derived primary attention, effort has disappeared. The kinaesthetic sensations indicate, not degree of attention, but rather inertia of attention; strained attention is, as we have seen, atten-

tion under difficulties; the very fact that we try to attend means that we are not giving full attention. It would, accordingly, be nearer the truth to say that, the more pronounced the effort, the lower is the degree of attention.

Whether this statement is strictly true is, however, a moot question. Everyday observation shows that we attend best under slight distraction. If we are too comfortable, if the conditions are, so to speak, too favourable for attention, we do not attend; we let our mind wander. Now experiment shows that observers in the laboratory also do their best under slight distraction; a modicum of effort, a little bit of resistance to overcome, calls out their full powers. If the two observations are parallel, then we must say that effort is neither directly nor inversely proportional to the height of the attention-wave; the relation of effort to degree of attention is equivocal. There would be nothing to surprise us in this result; consciousness is exceedingly complex, and the nervous system upon which consciousness depends is exceedingly complicated. But are the observations parallel? The laboratory observers will not, in any case, give more than secondary attention; and the slight distraction, thrown in by the experimenter, may help them because it standardises the difficulties under which they attend; they are henceforth working against a single, constant difficulty, instead of meeting all sorts of distracting influences. On the other hand, a chair that is too luxurious to work in is a chair that favours primary attention, and letting the mind wander is simply a form of primary attention, — it is attention to ideas that fit in with the present contents of consciousness. On the whole, then, these observations do not appear to contradict the statement that, the greater the effort, the lower is the degree of attention. Still, this statement does not, of itself, bring us appreciably nearer to a measurement of attention.

In theory, the most promising method of measuring the attention would seem to be this: to determine, introspectively, how many degrees of clearness can be distin-

guished in the various departments of sense, and then to bring every degree of clearness into relation with a definite sort and amount of distraction. We should thus have degree of clearness correlated with intensity of distracting stimulus; in other words, we should know the highest degree of attention attainable with a given amount of distraction; and we might accordingly use the numerical value of the distractor as a measure of the degree of attention. If we knew, for instance, that a certain sensation may exist in ten different degrees of clearness: and if we had at our disposal ten stimuli which, introduced by way of distraction, would reduce this sensation from the corresponding degree of clearness to total obscurity: then we might calculate, from the effect of a particular distractor in the particular case, what fraction of maximal attention the observer was giving to the matter in hand. The method is cumbrous, and difficult to work out; but the writer believes that it may, some day, be successfully applied.

In the meantime, many rough tests of degree of attention have been devised for practical purposes. It is plain, for instance, that uniformity of performance, the maintenance of a steady level of achievement without marked variation from the average in either direction, indicates sustained attention, while the alternation of very good and very poor work indicates a vacillating attention. Tests of this kind are valuable so far as they go; but they cannot take the place of an exact psychological determination.

§ 83. **Accommodation and Inertia of Attention.** — We saw in § 76 that congruity with the contents of consciousness is one of the determinants of primary attention. It follows from this fact that, if two stimuli are presented for attention at the same time, the one of which is and the other is

not congruent with ideas already present, they will reach the crest of the attention-wave, not together, but in succession; the stimulus which fits in with the general trend of consciousness will outstrip its rival. We speak, in such cases, of a predisposition or accommodation of attention to a certain impression.

The fact of accommodation of attention may be illustrated by means of the arrangement shown in Fig. 44. A bell-metronome is fitted with a cardboard arc, whose radius is the length of the pendulum. Scale divisions of 5° are laid off upon the circumference, the zero-point corresponding to the vertical position of the pendulum; an arrow-head of red paper serves as a pointer. The metronome is set to the rate of, say, 72 in the minute, and the bell rings at every complete oscillation. In the instrument used by the writer, the bell sounds when the pointer is at 22°.

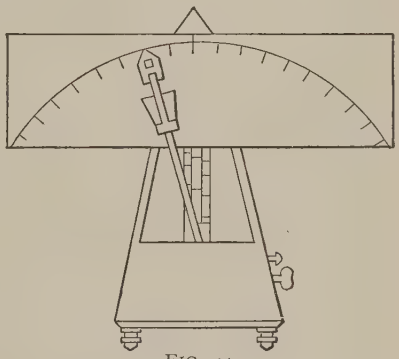


FIG. 44.

The pendulum is released, and the observer is asked to say how far the pointer has travelled when the bell rings. In a first observation, he is directed to attend to the moving pointer; the sound of the bell is secondary, — it floats, so to speak, upon the main current of visual change. Under these conditions, the pointer carries the bell out; the sound is not heard, on the average, until the pendulum points to 30°. In a second observation, he is directed to attend to the bell; the movement of the pointer is now secondary, — the expected bell-strokes stand out upon an indifferent shifting field. Under these conditions, the region of subjective coincidence lies between 10° and 15°. It is evident that, when the pointer is the main object of attention, the bell

stroke lags behind; and that, when the bell is the object of attention, the pointer lags behind. In the first case, the pointer gets to 30° before the bell (which rang at 22°) is heard; in the second, the bell is heard (at 22°) when the observed position of the pointer is only some 15°. The special accommodation of the attention may separate the two impressions by as much as 10° of the scale.

The same result appears even if no special directions are given to the observer. A dial is furnished with a circular scale, and a pointer is made to revolve before it, very much as a clock-hand revolves before the face of the clock. Once in every revolution, when the pointer has reached a certain scale-mark, a bell-stroke sounds. The observer is asked to say where the pointer is when the bell rings: no further instruction is given. He accordingly follows the course of the pointer with his eye, and in the first revolution refers the sound to some region of the circle. The second revolution narrows this region; the third narrows it still more; until finally there are only a few scale divisions with which the bell appears to coincide. In the meantime, attention has been sharpening to the sound; an accommodation of attention has taken place; the observer is predisposed to hear the bell at a certain instant. The instant comes; the bell-stroke rises at once to the higher conscious level; and there goes along with it the visual impression, not of the scale-mark with which it was objectively coincident, but of a scale-mark that the pointer had already traversed when the hammer struck the gong. It is as if there were a race to the top of consciousness, and the sound, outstripping the sight with which it started from the scratch, finishes abreast of a sight that had been given a certain handicap. The time-allowance that the sight receives is offset by the advantage accruing to the sound through accommodation of attention.

The time required for the accommodation of attention is about one and a half seconds. Hence, whenever quick and accurate observation is required in the psychological laboratory, it is customary to give a signal to the observer

a short two seconds before the stimulus is presented. This is the rule when a single accommodation is required. If the stimuli are frequently repeated, the attention is able, within certain fairly wide limits, to adapt itself to their rate of succession. It is possible, for instance, to read a rhythmical form into sounds that are as little as a fifth of a second and as much as three seconds apart (§ 80). The attention can accommodate itself to any rate between these extremes.

Accommodation implies inertia; and we find, in fact, that it is easier to continue a certain direction of attention than it is to strike out on a new path. You can follow the movement of a single instrument in the orchestra better, when there has been solo-playing before, than when the whole group of instruments begin together; you can finish a conversation, once begun, at a distance that would render the words of an unexpected question altogether inaudible; you can trace the upward course of a fire-balloon to a point at which it would otherwise be invisible. In the same way, it is difficult to break away from a current train of thought, and to give your full attention to a letter or a caller; and it is difficult to settle down again to your work after such an interruption. The description of inertia of attention must, unfortunately, be left in these general terms; no special investigation of its laws has as yet been made.

§ 84. **The Bodily Conditions of Attention.** —Theories of attention are as plentiful as theories of affection. Some of them have been worked out with great ingenuity of detail. Since, however, all alike are in large measure speculative, we shall here simply indicate, in bare outline,

what seems to be the most reasonable explanation of the attentive consciousness.

Neurologists are agreed that one nervous excitation may influence another in two opposite ways: by helping and by hindering, or, in technical terms, by facilitation and by inhibition. We may take an elementary illustration in each case. If a weak cutaneous stimulus is applied to the hind foot of a decerebrised frog, there is no visible effect; the limb remains passive. But if at the same time a light is flashed into the eye, the leg-muscles may respond by a strong contraction. Here we must suppose that the two excitations, the cutaneous and the visual, have in some way reinforced each other; there is nervous facilitation. Again, a pressure applied to one part of the frog's body will touch off a croak; a strong pressure applied to a different part will touch off a muscular contraction. But if the two pressures are applied together, the frog does not both croak and move; he does nothing at all; there is no response to the stimuli. Here we must suppose that the two excitations interfere with each other; there is nervous inhibition.

It seems plain that the conditions of the attentive consciousness are of these two kinds. The clear processes, at the crest of the attention-wave, are processes whose underlying excitations have been facilitated. Similarly, the obscure processes, at the lower level of consciousness, are processes whose underlying excitations have been inhibited. The attentive consciousness is thus conditioned upon the interplay of cortical facilitation and cortical inhibition.

When, however, we ask for further details; when we try to form a picture of what is really going on in the

cortex when facilitation and inhibition are at work; then we are thrown back upon speculation. Wundt, for instance, believes that there is a special cortical centre, in the frontal lobes, from which the inhibitions proceed.[1] His opinion carries great weight, and is supported by a very considerable body of evidence. Nevertheless, the action of what he terms the apperception centre is confessedly hypothetical. Other psychologists believe that the processes of facilitation and inhibition are diffused more or less widely over the entire cortex. But their agreement extends no further. One recent theory maintains, for example, that the clearness or vividness of a sensation is due to the complexity of cortical organisation, — to the numerous interconnections of the nervous elements, the extreme variability of the resistances which they offer, and the number of alternative paths that may be opened in turn to the excitation-process. Another lays equal stress upon this complexity of organisation, but uses it in precisely the opposite way: a sensation is clear when its excitation-process is strictly local, and obscure when the excitation-process is spread abroad into many cross-paths and over many systems of nervous elements. No one can say which is right and which is wrong; no one can say, for that matter, if either is right or if both are wrong. We must therefore suspend judgment, until more is known of the physiological mechanism of inhibition and facilitation.

[1] Wundt explains attention in terms of inhibition only, not of inhibition and facilitation.

References for Further Reading

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